ICFA Beam Dynamics Newsletter, No. 15

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1: From the chairman

Kohji Hirata `hirata@kekvax.kek.jp` The Chairman of ICFA Beam Dynamics Panel

The chairman of the beam dynamics panel is a very hard job. Besides taking care of this newsletter, I should travel and visit various laboratories much more than the case if I were not so. Although this activity takes a lot of time and little is left for me to investigate many interesting problems in beam dynamics, it is nevertheless enjoyable not only because I can have many touristic kinds of experiences but also because I can meet many accelerator physicists working in very different places.

Whatever accelerator laboratories I visit, I always feel the same atmosphere of the accelerator community. What is the common features of accelerator physicists? I think it consist of the fact that all of us 'love' beams and are happy when there is a beam. We always try to have better beams, whether the users want it or not. Sometimes, I suspect that the users do not like beam physics activities. They might be afraid if we play with instabilities and enjoy every day forgetting the performance of the accelerators. Such a feeling seems ridiculous and even the opposite for me. (It is of course possible that what we think improvement does not coincide with the improvement seen from the users. In a radiation source, for example, if we provide a beam with very small emittance at the sacrifice of the intensity, some users might complain. In such a case, the users should define the "improvement" as the rule of the game. This rule should be stated in terms of measurable quantities.)

I think it evident that in order to have a better beam or to construct better accelerators, the (right) beam dynamics consideration is indispensable. The beam dynamics activity is first to observe the beam and to apply the existing theories appropriately and develop new theories whenever it is necessary. (I feel it is necessary frequently, indeed). In this case, it is very important that we are good physicists and are well motivated. But more important seems that we enjoy it. We like to improve the beam because it is enjoyable: "those who know it are not better than those who like it and those who like it are not better than those who enjoy it [1]".

Of course, the beam we enjoy is not necessarily limited to the beam in our individual projects and laboratories. Also, to enjoy the beam, we do not need to live near the beam. The beam is international. I want to make this *Newsletter* the place where we enjoy the beam together with other members of the same community.

All the articles in this *Newsletter* are to be considered as *informal*. In the articles in journals, the authors try to show what is achieved. In this *Newsletter*, I think it more appropriate that authors try to explain what is not understood and how the problem is interesting. If the journal papers correspond to the talks in a workshop, the articles in the *Newsletter* may correspond to the conversation during the coffee breaks. The *Letters to Editors* is even more informal. It might correspond to the talks in the workshop dinner.

All above is my personal consideration and does not represent the opinion of the panel. I hope you have enjoyed reading it.

Reference

[1] Confucius, Analects, publisher unknown.

There were some changes in the membership of the panel. Dr. Balbekov was replaced by Dr. Ivanov, Dr. Labedev and Dr. Siemann have moved to another panel. The chairman thanks them for their long standing contributions to the Panel.

2: Letters to the Editors

2.1 From Marica Biagini

Dear Editors,

I would like to submit to draw an attention of the accelerator physicists community to the importance of exchange of information on data of the operational e^+e^- storage rings (I limit myself to these machines being involved in this field).

Therefore I would like to propose the creation of a Database containing either fixed and dynamical machine parameters. It would be useful to know, together with the collider performances, all the related (measured or computed) parameters as lifetime, beta functions at the IPs, emittance, etc. Of course it is a very difficult task: one problem is to maintain this updated (but we have WEB to provide it!) the other is that often the best results are obtained after a number of machine adjustments that are difficult to quantify. This means that the data will always be in some way ”incomplete”, but still an effort should be made.

Mario Bassetti and myself have worked on a fit of the maximum linear beam-beam tune-shift parameter measured on several colliders, from VEPP-2M to LEP. The data we used were mostly extracted from review papers and were in some cases based on older published data. Since we need a lot of information on the operational parameters when the maximum tune shift was achieved, in many cases we had to extrapolate them from published data that were not always complete. In most cases published papers contain the maximum tune-shift reached, together with the maximum luminosity obtained and the maximum current stored, even though they are seldom measured at the same time. I use this occasion to apologize with those who complained our data were not updated. We are working on it.

I think this Database would be very helpful for the community. Of course several people from different laboratories should cooperate to create it and keep it updated. It would be very interesting to set a “task force” to start working as soon as possible.

In any case I wish to thank the ICFA Newsletters for letting me express my concerns on this subject.

Sincerely yours,

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2.2 From John Galambos

Dear S.Y.,

I’d like to take this opportunity to offer some thoughts on the use of C++ (and lack of use) in scientific computing. By way of background, I am a relative newcomer to the accelerator physics field, coming from the fusion field about a year ago. I noticed that the majority of the ”workhorse” codes available for distribution (MAD, TRANSPORT, PARMILA, COSY-INFINITY) are FORTRAN codes - a similar state as in fusion. My feeling is that the community needs to take a more pro-active stance in developing new object-oriented methods (e.g. C++) for the scientific computing needs.

Like many of us in science, I started off using FORTRAN pretty much exclusively. However, about 6 years ago I had the good fortune to collaborate with a C++ savvy colleague, and was exposed to the virtues of using object oriented techniques in scientific codes. Originally I was dragged into using C++, and it was some time before I really understood the concepts behind object oriented programming. My experience has convinced me that we need to join the rest of the world and adopt the newer programming paradigms. I don't aim to offer an exhaustive explanation of object oriented techniques here (as these benefits and techniques are discussed widely elsewhere [1,2]). Rather I'll try and offer a few examples which may shed light on the scientific applications - and hopefully convince someone else to try it.

A primary feature of object oriented programming is being able to create your own types. In FORTRAN, you're pretty much stuck with real, integer, complex, and character types. Given the ability to create a type (using classes in C++) for the entities you're actually trying to model opens up a completely new programming technique. This is sometimes referred to as raising the abstraction level. For example, a lattice design program might have an ”element” class which contains all the general ”stuff” you need to know about each lattice element. Information within a class can be tightly protected against accidental overwriting (called ”encapsulation”). With C++ you can readily ”inherit” general type features into more specific features. For instance, the lattice element class could be inherited by a more specific derived class for dipoles. Another feature known as polymorphism allows you to implement an action in a general way, across different derived classes, without resorting to clumsy, hard to upkeep if/else clauses. Although I've only scratched the surface here, I will say that I've found the use of object oriented techniques results in codes which are more flexible, and easier to upkeep/expand.

Two common criticisms of C++ use for scientific applications are 1) a speed penalty relative to FORTRAN, and 2) a lack of supporting numerical libraries. Recently, the advent of a feature called expression templates in C++ has eliminated the speed penalty [3,4,5,6], with C++ codes performing neck and neck with optimized FORTRAN in vector loop comparisons. FORTRAN no doubt has a stronger support base of numerical libraries, but the C++ base is rapidly increasing [7].

My experience leads me to believe that excuses such as ”I don't have time to learn a new language”, or ”I can do everything I need to do in FORTRAN”, etc. only put off the inevitable transition. Certainly there is a learning curve associated with C++, but I've found it to be well worth the effort. Try it, you'll like it.

Sincerely,

John Galambos `galambosjd@ornl.gov` Oak Ridge National Lab.

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3: Workshop Reports

3.1 Report on 13th Advanced ICFA Beam Dynamics Workshop and 1st ICFA Novel and Advanced Accelerator Workshop on the Second Generation Plasma Accelerators

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This workshop chaired by C. Pellegrini (UCLA) and A. Ogata (KEK) was held at Kyoto Research Park,14 to 18 July 1997. It was joined by 1st JAERI Workshop on Ultrashort-Pulse Ultrahigh-Power Lasers and Simulations for Laser-Plasma Interactions. The whole workshop was called “Joint ICFA/ JAERI-Kansai International Workshop ’97”. JAERI, Japan Atomic Energy Research Institute which has now its laboratory for laser/plasma acceleration, has jointly hosted the workshop with KEK. These two workshops are loosely coupled. All the participants were free to join either of the workshops. Interchange of discussions between two parties was encouraged.

Recent theoretical and experimental results on acceleration of particle beams using plasmas and/or lasers have led to an expansion of the research in this field at many laboratories and universities, and in many countries. Accelerating fields over 10 GeV/m have been experimentally demonstrated in the laser/plasma systems. These results became interesting also because of the exciting progress in the technology of high peak power lasers, and the expectation that in the near future their cost will be reduced, while their average power and their efficiency will increase. A new set of experiments are now being designed to show that the beams accelerated by these laser/plasma systems can have the intensity and phase-space density required for practical accelerators to be used industrial, medical, and academic purposes including high energy colliders. These experiments should produce their initial results in the next two to five years.

This workshop dedicated to the topic of beam quality in laser/plasma accelerators was thus organized in view of the present strong, growing and successful activity in this field, and its promise for future developments in accelerators.

The number of participants in the joint workshop was 105, from Japan(69), USA(19), Russia(6), France(5),Italy(4), Greece(1) and China(1). Status reports were invited in plenary sessions, which were from Utsunomiya Univ.(Nishida, mainly on $v_p \times B$ acceleration), UCLA(Clayton on PBWA), KEK-JAERI-U.Tokyo Collaboration (Dewa on LWFA), Ecole Polytechnique (Amiranoff on LWFA) and BINP (Kudryavtsev on PWFA). M. Downer of Texas Univ. gave a review talk on LWFA. The PWFA at ANL and SLAC were introduced by Barov and Assmann, respectively, together with the plasma lens project at SLAC by P.Chen also in the plenary session. No poster session was held. For techical terms such as PBWA, see Ref.[1].

The workshop had three working groups.

group I : injection and dynamics of accelerated beams (7 talks), chaired by J.Rosenzweig and K. Yokoya

group II : dynamics of plasma-wave drivers (lasers in LWFA and beams in PWFA) and plasmas (10 talks), chaired by T. Katsouleas and K.Nakajima

group III : near-term and far-term applications of plasma accelerators (9 talks), chaired by T.Tajima and P.Chen

Rosenzweig, Katsouleas and Tajima made review talks and summary talks for their groups. We also had joint sessions between group I and II (9 talks), and group II and III (3 talks).

Two main topics of the group I were the external injection (by Bernard, W.Mori, including laser cathode by Uesaka, Wang, Rosenzweig) and the plasma cathode (Hemker, Umstadter). In the latter, the laser field captures the plasma electrons and accelerates them. Timing/phase locking between injection beams and drivers for acceleration was also a big topic. Kirihara reported beam stabilization by plasmas in $v_p \times B$ acceleration.

Rosenzweig, the group chairman, pointed out the necessity of common terminology to specify the beam qualities of plasma accelerators and proposed a new definition of brightness and introduction of “focusability”.

In the group I-II joint session, Clayton reported the RAL experiments. PWFA projects was reported by Gai, Lotov and Rosenzweig and PBWA simulation was reported by W. Mori. Andreev discussed channeling. A scheme without a plasma was proposed by Sugihara. An exotic topic was provided by Hojo, particle acceleration by subcyclic laser pulse. Ogata tried to describe plasma acceleration using linac terminology such as shunt impedance, quality factor, etc..

Talks of the group II had wide range. Downer reviewed lasers for accelerators. Laser-plasma interactions including wavebreaking were discussed by Bulanov, W.Mori, M.Mori, Koga and Pegoraro who used a thin foil model. Chen introduced laser pulse shaping for LWFA and Umstadter introduced use of pulse trains for LWFA. Nakajima reported JAERI project.

In the group III, the first topic was near-term applications such as x-ray generation (Ruhl, Chen, Ueshima, Barty, Pogorelsky, Endo and Washio). Laser Larmor x-rays and Compton x-rays were compared with those from conventional sources, synchrotron radiation and FEL. Testing of Unruh radiation in plasma wavefronts proposed by Chen must be another interesting application. Mima proposed ion acceleration. The second topic was the long-term applications. A typical example was the linear collider design (Tajima).

This second topic was discussed also at the joint session of the groups II and III. Bernard made calculation of 1GeV LWFA in linear regime, and Pogorelsky insisted the advantages of $\mathrm{CO_2}$ lasers in the LWFA. Rosenzweig gave a ”strawman” design of the PWFA-based collider. In the summary of group I, which was the last session of the working group and to which most people attended, comparison was made between PWFA family (two designs made by Lotov using driver of a pulse train and Rosenzweig using the blow-out regime) and LWFA family (two designs by Bernard and Pogorelsky).

We attended the plenary session of the JAERI Workshop which had 5 talks. Tajima made a review entitled ”high field science”. Other four talks by Barty, Yamakawa, Chambaret and Mourou were on the laser development in their laboratories.

Most of the transparencies shown in the workshop are available on the web page,

`http://ogata-p95.kek.jp/gion.html.`

The word ”gion” used here is after the Gion Festival, the most traditional festival in Kyoto on July 16 and 17, during the workshop. Though it rained during the parade, we enjoyed. The proceedings will be published as a special issue of the Nuclear Instruments and Methods in Physics Research A. All papers contributed to the proceedings were refereed.

Reference:
[1] A. Ogata, in ICFA Beam Dynamics Newsletter No.12 (1996).

3.2 Nonlinear and Stochastic Beam Dynamics in Accelerators - A Challenge to Theoretical and Computational Physics, Lüneburg, September 29 - October 3, 1997

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Accelerators have become an important tool in basic research. For example, storage rings are used as synchrotron light sources with broad applications in physics, chemistry, medicine and applied science and colliders have become an indispensable tool in high energy physics. The optimal performance of these devices requires a good understanding of the physics of charged particle beams. This is especially true for new projects which require higher energy, higher brightness, lower emittance, higher density etc.

A particle beam constitutes a complicated many body system subject to

- external electromagnetic fields
- induced fields (wakefields) and space charge
- restgas scattering and intrabeam scattering
- radiation
- fields of counter rotating beam

Theoretical tools to treat such systems are based on the Liouville equation, the Vlasov-Maxwell equation and the Fokker-Planck equation. In order to discuss some of these topics DESY has organized a workshop in Lüneburg from September 29 to October 3. About 40 physicists and mathematicians from universities and laboratories in Europe and the US met to give a view of their research fields and to discuss common techniques and concepts. The workshop concentrated on three questions:

- what are the important accelerator physics problems?
- what kind of theoretical tools and concepts are available?
- what are the computational implications?

In a series of review and tutorial talks the following topics were covered:

- mathematical concepts and tools for analyzing stochastic dynamical systems: the single realization problem (J. Ellison)
- the adiabatic invariant in classical mechanics (J. Henrard)
- Nekhoroshev’s theorem and particle channeling in crystals (S. Dumas)
- diffusion behaviour in perturbed Hamiltonian systems (A. Bazzani)
- computational aspects of normal form theory with applications to polarized proton beam dynamics (V. Balandin)
- formation and control of halos induced by space charge (J. Lagniel)

- collisions and entropy in charged particle beams (J. Struckmeier)
- computational aspects of Vlasov-Maxwell systems (H. Ruhl)
- beam dynamics issues of future synchrotron light sources and FEL's (L. Rivkin)
- old and new collective effects in circular accelerators: single and multibunch phenomena (F. Ruggiero).

In the contributed talks the speakers discussed:

- analysis of slowly modulated Hamiltonian systems by using the ”time-energy” map (L. Raymond)
- stability and diffusion in 4-dimensional accelerator maps including weak damping and noise (T. Bountis)
- some limit theorems for linear oscillators with noise in the coefficients (V. Balandin)
- space charge and nonlinear betatronic dynamics (G. Franchetti)
- chaotic motion and halo formation in an intense beam propagating in a quadrupole channel surrounded by a cylindric pipe (A. Pisent)
- nonlinear solution for bunch motion in the presence of a reactive impedance (E. Shaposhnikova)
- theory of solitary structures in unbunched beams in synchrotrons (H. Schamel)
- large scale simulation of intense beam using high performance computers (R.D. Ryne, S. Habib)
- space charge in multi-dimensional beams (I. Hofmann)
- analytical solutions of Fokker-Planck type equations (G. Dattoli)
- numerical solution of the Fokker-Planck equation (E. Johnson)
- Fokker-Planck equations in accelerator physics (M.P. Zorzano Mier)
- depolarization of a beam of charged particles in single pass optical systems (N. Golubeva)
- nonlinear effects in polarized proton beams (G. Hoffstätter)
- beam dynamics with quantum theory formalism (M. Pusterla)
- first experiments related to the nonlinear behaviour of the beam in COSY (S. Martin)
- beam shaping at COSY (H. Stockhorst)
- analytical and numerical methods to investigate the dynamic aperture (W. Scandale)
- diffusion due to tune modulation: an approach based on dynamic aperture extrapolation (E. Todesco)
- dynamic aperture studies for the LHC (M. Böge)

- sorting of LHC dipoles (R. Bartolini)
- normal form via tracking or beam data (F. Schmidt).

A special session of the workshop was reserved for the presentation of the results of the European network ”Nonlinear Problems in Beam Dynamics and Transport”. G. Turchetti, the main coordinator of this net, summarized the main results of this collaboration which concentrated on

- stability and structure of phase space
- diffusion and transport
- high intensity and collective phenomena.

This European net has been funded for more than three years and has proven to be very efficient. The regular exchange of ideas and the frequent visits of the researchers involved to the various partner institutions has not only strengthened the collaboration between universities and laboratories but has also provided an excellent transfer of knowledge and expertise. Furthermore, this collaboration has been ideally suited for training and educating young scientists in the field of beam dynamics. It was the common belief of the net members that the collaboration should be continued in the future. The research topics of a new network and the detailed scientific proposal will be discussed in the next year.

At this point it is a pleasure to thank the staff of the workshop hotel for the friendly and efficient service which allowed a smooth running of the meeting. The success of the workshop was largely due to the excellent and stimulating lectures given by all the speakers and thanks are due to all participants for making this a lively and exciting meeting. However, our deepest thanks are to S. Sievers for her tremendous help in preparing and running this workshop. Last but not least this conference would not have been possible without the generous financial support from DESY.

3.3 The Third Japanese Beam Physics Meeting

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A workshop on beam physics, sponsored by Japan Synchrotron Radiation Research Institute (JASRI), was held on September 25 and 26 at the SPring-8 laboratory in Hyogo, Japan. It is the third annual meeting organized by the Japanese Beam Physics Club (See ICFA Beam Dynamics Newsletter No.12). There were over sixty participants, and the following oral presentations were given:

- Study of laser-particle beam interactions at the SPring-8 linac (A. Mizuno, SPring-8)
- Beam-photoelectron instability (K. Ohmi, KEK) Laser cooling and phase transition of ion beams (H. Okamoto)
- Commissioning of SPring-8 (H. Tanaka, SPring-8)
- Space-charge effects in FEL (S. Hiramatsu, KEK)
- The influence of half and non-half integer resonances on the beam dynamics of the RIKEN superconducting cyclotron (T. Mitsumoto, RIKEN)

- On the existence and uniqueness of the solution to the Haissinski equation (Y. Shobuda, Tohoku Univ.)
- Experimental study of positive and negative momentum compaction lattice (H. Hama, Institute of Molecular Science)
- Development of an rf cavity for high brightness SOR ring (T. Ozeki, Tokyo Univ.)
- Physics of high brightness beam transport without halo formation (Y. Batygin, RIKEN)
- Control of betatron oscillation frequency by means of an RFQ (T. Endo, Osaka Univ.)
- Development of the resonant transition radiation source of X-ray based on electron beams (C. Yajima, Kyoto Univ.)
- Resistive wall heating in the SPring-8 undulators (T. Hara, SPring-8)
- Evaluation of femto-second X-rays produced by inverse Compton scattering (A. Endo, Electrotechnical Laboratory)
- Coherent bremsstrahlung and FEL using a compact accelerator (E. Minehara, JAERI)
- Estimate and cure of the beam instabilities at SPring-8 (T. Nakamura, SPring-8) Nonlinear Compton scattering (H. Matsukado, Hiroshima Univ.)
- Possibility of X-ray FEL in a low-emittance ring (Y. Minehara, SPring-8)
- Pico-second radiolysis by pico-second pulsed electron beam and femto-second laser (Y. Yoshida, Osaka Univ.)

Besides these talks, there were sixteen poster presentations given by graduate students. After all the program was completed, we made some discussions on the future strategy of promoting the beam physics activities in Japan. Establishing the division of beam physics in the Japanese Physical Society, similar to that in APS, was considered as one of the future issues. We also had an announcement regarding the Beam Physics Winter School in March, 1998, sponsored by RIKEN.

3.4 6-th Accelerator Physics Symposium of PASC

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The Accelerator Physics Panel of Particle Accelerator Society of China (PASC) held its 6-th Symposium from August 27 to September 1, 1997 in a wonderful mountain area Zhang-jia-jie, Hunan Province. About 45 participants from universities and research laboratories across the country attended the symposium, in which 44 papers were reported. In the symposium, the design studies of the Beijing Tau/charm Factory, Shanghai Synchrotron Radiation Light Source and Langzhou Cooling Storage Rings were presented; the results of beam physics studies with the Beijing Electron-Positron Collider, the Hefei Synchrotron Radiation Light Source and Langzhou Heavy Ion Facility were reported; and many analytic and experimental researches on linear and nonlinear phenomena, the accelerator structure for linear colliders, the AMS Cycrotron, beam-cavity interactions, ion effects, space charge effects, beam-photoelectron interactions, free electron laser studies and other subjects were discussed. It was proposed that the 7-th symposium would be held in Chengde, Hebei Province in 1999.

3.5 Report on the 7-th Asia Pacific Physics Conference

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The 7th Asia Pacific Physics Conference (7APPC) was held from Aug. 19 to 23, 1997, at the Friendship Hotel in Beijing, China. The conference was sponsored by the Chinese Physics Society (CPS) and the Institute of High Energy Physics (IHEP) of Chinese Academy of Sciences (CAS). As one of the largest physics conferences in Asia Pacific region, it concerned nine subjects of physics. They were condensed matter physics, particle physics, accelerator physics, atomic & molecular physics, plasma physics, nuclear physics, optics, applied physics and physics-general & statistical physics, covering most of the modern physics fields. The Nobel laureate, Prof. C.N. Yang, gave a report on Bose-Einstein Condensation in the last plenary session.

As a branch of modern physics, accelerator physics occupied a crucial position on 7APPC, on which 19 formal representatives from 12 laboratories in Asia Pacific region gave talks in two days' parallel sessions. Their contributions revealed most of the recent accelerator activities in this region.

Scientists from KEK, Japan, reviewed its current project, KEK B-Factory, and two future projects, JHF and JLC. The KEK B-Factory goes smoothly towards its final goal. In the JHF project, the lattice of the 50-GeV synchrotron has some features like four long straight sections (60m), transition free, phase advance below 90 degree to avoid any strong resonance of the self space-charge force coupled with the beam-envelope modulation, and maximum tunability. In the 3-GeV synchrotron of JHF, the beam loss and related issues become the key points to solve. The RHIC project of BNL in USA and its physical and technical challenges were reported. In RHIC, intra-beam scattering will be cured with 3-dimensional cooling. Error compensation has been carried out by tuning trims, amplitude dependent body-ends compensation, low-beta sorting and lumped triplet multi-layer corrector package. Techniques of colloidal-cell and magnetic antenna, and choreographed welding are used in magnet alignment. A ”matched first order” transition jump scheme is designed to solve the problems related with transition crossing. Another promising project, Shanghai Synchrotron Radiation Facility (SSRF), attracted attendants' interest. Four features consist the main considerations of the SSRF lattice design. They are small emittance, the possibility of using superconducting dipoles, super long straight sections and a large number of periods (16) to allow installing as many insertions as possible..

The joint experiment of fast ion instability (FII) done in PAL, Korea was summarized. A new phenomenon is just observed in the experiment, that is, when current is fixed, the longer the bunch train, the weaker the instability. The FII will affect the KEK-B seriously as the current in its HER is so high. The experimental studies on photon-electron instability carried out jointly by IHEP and KEK in the BEPC was recalled. This kind of transverse instability strongly depends on chromaticity and bunch spacing. The mechanism is clear enough, while its cure remains to be studied more. A lattice design for the Beijing Tau-Charm Factory (BTCF) with negative momentum compaction factor was discussed in the session. It has apparent advantages on controlling bunch lengthening happening in electron machines. But the corresponding increase of energy spread becomes a big problem as Super-Aco's experiments showed.

Experts from PAL of Korea depicted accelerator science and beam dynamics activities in their labs. Two SLAC specialists showed their research on non-linearity for PEPII B-Factory lattice and the philosophy of accelerator modeling. Chinese researchers played an active role in the parallel sessions. The status of BEPC and its possible future, BTCF/BEPCII, were reported, meanwhile, the Phase II project of NSRL in Hefei and upgrades of HIRFL-CSR in Lanzhou were figured.

Scientist from Chinese Taiwan reported the recent progresses on beam physics in SRRC and many other institutions. With the development of applied sciences in China, accelerators such as medically used cyclotron, low energy electron accelerator for radiotherapy, radiography and irradiation processing, RFQ accelerators and radiative nuclear beam facility got much more supports than ever before. All these were widely discussed and got high praise in the conference.

The 7APPC was fruitful with the efforts of all the representatives, and the parallel sessions on accelerator physics as well. Participants of accelerator physics sessions even shortened the coffee break with their active discussions. New ideas and different opinions were exchanged on the meeting. Besides the indoor activities, some attendants had a visit on IHEP and Chinese Institute of Atom Engineering (CIAE) in Beijing, and gave seminars there. The next conference, 8APPC, will be held in Chinese Taipei, in the year of 2000.

4: Activity Reports

4.1 DAΦNE First Commissioning Results

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The first electron beam has been stored into the electron ring of the DAΦNE collider on October 25, 1997 at 10.30 p.m. During a shift started at 2 p.m. the 510 MeV electron beam has been transported to the injection point of the electron Main Ring. With the RF cavity off it was possible to keep the beam inside the ring for about 0.3 ms, which is the maximum value allowed by the energy loss due to the emission of synchrotron radiation and the aperture of the vacuum chamber (DAΦNE spiraling time). The RF cavity was then switched on and the beam captured and stored in the ring. The position of the beam along the ring has been measured by means of the beam position monitors and found to be in agreement with the alignment tolerance. (max. orbit deviation = $\sim$1 cm hor. and $\sim$ 0.5 cm vert.) The magnets, including wigglers, were set to the calculated current taking into account the contribution from the fringing fields, and the discrepancy between measured and theoretical betatron tunes was less than 0.02 in both planes. Theoretical and measured chromaticities were also in very good agreement. Lifetime was $\sim$ 1 min, consistent with an average pressure of 10^{-7} torr due to the outgassing of vacuum pipe due to the first synchrotron light. Multistacking in a single bunch was also successfully performed, reaching 2 mA stored current, limited by safety reasons and pressure rise.

The positron ring will be ready for beam by middle of November when non stop commissioning will begin. The newest information on DAΦNE will be shown in WWW page

`http://www.lnf.infn.it/acceleratori/dafne/dafne.html`

4.2 Quantum-Beamsstrahlung Laser Collider

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An e^+e^- linear collider at energies beyond a TeV runs into a problem of severe beamsstrahlung, characterized by Υ on the order of unity (and beyond). In the regime of extremely high Υ the beams-strahlung may be largely suppressed due to the quantum effect. In the design of an e^+e^- collider there are two ways to satisfy the collider physics constraints. One is to decrease the number of particles per bunch (and thus to increase the repetition rate) and the other is to decrease the longitudinal bunch length. The former approach can limit Υ, while the latter boosts it. (It may be useful to reevaluate the future collider parameters in view of this.) The laser wakefield driver for a collider in comparison with the microwave driver naturally offers a very short bunch length, which is appropriate for the latter collider option. We show that this choice of collider design with a short bunch length and high Υ has advantages and provide sample design parameters at 5 TeV.

Such sample design parameters challenge us in a number of fronts, such as the preservation of high quality bunches, efficient high repetition rate lasers, etc. The collision point physics simulated by the CAIN code shows a surprisingly well preserved luminosity spectrum.

4.2.1 Introduction

In this article we report a recent work of a strawman's design based on the collaboration among the LBL, KEK, and The University of Texas at Austin and suggest where the laser-based accelerators in the future need further developments. The work was reported at the Advanced Acceleration Conference (Lake Tahoe, 1996) by M. Xie, T. Tajima, K. Yokoya, and S. Chattopadyay [1]. It is believed that a linear collider at around 1 TeV center of mass energy can be built more or less with existing technologies. But it is practically difficult to go much beyond that energy without employing a new, yet largely untested method of acceleration. However, apart from knowing the details of the future technologies, certain collider constraints on electron and positron beam parameters are general, and have to be satisfied, e.g. available wall plug power and the constraints imposed by collision processes: beamsstrahlung, disruption, backgrounds, etc. We have examined collider performance at the final interaction point (IP) of e^+e^- collider over a large space of beam parameters. It becomes increasingly necessary at higher energy to operate colliders in high Υ regime and use to our advantage the quantum effect to suppress beamsstrahlung. Here Υ is the ratio of the (classically calculated) beamsstrahlung photon energy to the beam electron (or positron) energy. Although the quantum suppression effect was known and studied before with simple models [2-5], it has not been checked with full-blown simulation at high Υ regime that have been considered in the paper by Xie *et al.* [1] (though several issues remain to be further checked). There are indeed several features revealed by this simulation, in particular in the differential luminosity spectrum, which is a crucial factor for collider detectors.

4.2.1.1 Collision Point Physics

An important collider performance parameter is the geometrical luminosity given by

$$\mathcal{L}_g = f_c N^2/4\pi\sigma_x\sigma_y$$

where f_c is the collision frequency, N is the number of particles per bunch, σ_x and σ_y are, respectively, the horizontal and vertical rms beam sizes at the IP. The real luminosity, however, depends on various dynamic processes at collision. Among them the most important ones are beamsstrahlung and disruption. These two processes are characterized by the beamsstrahlung parameter

$$\Upsilon = 5r_e^2\gamma N/6\alpha\sigma_z(\sigma_x+\sigma_y),$$

and the disruption parameter $D_y = 2r_e N\sigma_z/\gamma\sigma_y(\sigma_x+\sigma_y)$, where γ is the Lorentz factor, r_e the classical electron radius, α the fine structure constant, and σ_z the rms bunch length. Beamsstrahlung is in classical regime if $\Upsilon \ll 1$, and strong quantum regime if $\Upsilon \gg 1$. The physical effect of beamsstrahlung is not directly reflected in the magnitude of Υ, but rather it is more conveniently monitored through the average number of emitted photons per electron $n_\gamma = 2.54(\alpha\sigma_z\Upsilon/\lambda_c\gamma)U_0(\Upsilon)$ and relative electron energy loss $\delta_E = 1.24(\alpha\sigma_z\Upsilon/\lambda_c\gamma)\Upsilon U_1(\Upsilon)$, where $\lambda_c = \hbar$/mc is the Compton wavelength, $U_0(\Upsilon) \approx 1/(1+\Upsilon^{2/3})^{1/2}$, and $U_1(\Upsilon) \approx 1/(1+(1.5\Upsilon)^{2/3})^2$.

The collider physics scaling laws may be epitomized [1] in two-dimensional parameter space $\{N, \sigma_z\}$ when $\{E_{\rm cm}, \mathcal{L}_g, P_b, R\}$ are considered fixed

$$f_c \sim 1/N, \quad \sigma_y \sim \sqrt{N}, \quad D_y \sim \sigma_z, \quad \Upsilon \sim \sqrt{N}/\sigma_z \tag{4.1}$$

$$n_\gamma \sim U_0(\Upsilon)\sqrt{N}, \quad \delta_E \sim \Upsilon U_1(\Upsilon)\sqrt{N}. \tag{4.2}$$

Table 4.1: One Example of Beam Parameters and Collider Physics Results of the 5 TeV Design [1]

P_b(MW)	$N(10^8)$	f_c(kHz)	ε_y(nm)	$\beta_y(\mu$m)	σ_y(nm)
2	0.5	50	2.2	22	0.1
$\sigma_z(\mu$m)	Υ	D_y	$F_{\rm Oide}$	n_γ(theo)	δ_E(theo)
0.32	3485	0.93	0.89	0.72	0.2
n_p(theo)	$\mathcal{L}_g(10^{35}\ {\rm cm}^{-2}{\rm s}^{-1})$	n_γ(sim)	δ_E(sim)	σ_e/E_0	n_p(sim)
0.19	1	1.9	0.38	0.42	0.28
$\mathcal{L}/\mathcal{L}_g(W_{\rm cm} \in 1\%)$	$\mathcal{L}/\mathcal{L}_g(W_{\rm cm} \in\ 10\%)$				
0.83	1.1				

In the limit $\Upsilon \gg 1$, $U_0(\Upsilon) \to 1/\Upsilon^{1/3}$, $\Upsilon U_1(\Upsilon) \to 1/\Upsilon^{1/3}$. Equation (2) becomes [1]

$$n_\gamma \sim (N\sigma_z)^{1/3}, \qquad \delta_E \sim (N\sigma_z)^{1/3}. \tag{4.3}$$

We see from Eqs. (4.1) and (4.2) that once in the high Υ regime there are two approaches to reduce the effects of beamsstrahlung: either by reducing N or by reducing σ_z. The consequences on the collider design and the implied restrictions on the approaches, however, can be quite different. Reducing N requires f_c to be increased and σ_y decreased, thus the approach is limited by the constraints on f_c and σ_y. Reducing σ_z, on the other hand, is not directly restricted in this regard. Also the dependencies of Υ on the two approaches are quite the opposite. The second approach clearly demonstrates the case that beamsstrahlung can indeed be suppressed by having larger Υ.

4.2.1.2 High Υ Physics with Short Bunches

Strong quantum beamsstrahlung physics with high Υ includes some important effects such as disruption and multiphoton processes [6]. A Monte-Carlo simulation code recently developed by Yokoya[7] was used to study QED processes at the IP for e^+e^- and $\gamma\gamma$ colliders [1]. Table 1 is the compilation of the design parameters [1] for a laser driven e^+e^- linear collider at 5 TeV, as well as consequential collider physics parameters. The differential e^+e^- luminosity for the parameter in Table 1 has been computed [1]. It is noted that the luminosity spectrum is characterized by an outstanding core at the full energy and a very broad, nearly flat halo. The outstanding core is more than two orders of magnitude above the halo. The sharpness and the high luminosity of the core is rather surprising but pleasantly so.

Another major deteriorating process at high Υ is coherent pair creation. The number of pairs created per primary electron, n_p, (Table 1) has been computed [1] based on formulas [6] and by simulations. According to the simulations the incoherent pair creation is 2 to 3 orders of magnitude smaller than that of the coherent pairs, thus negligible. Finally, we point out that such a differential luminosity spectrum should be rigorously assessed together with the background of beamsstrahlung photons and coherent pairs from the point of view of particle physics and detector considerations. In particular, their angular distribution will critically determine the detector design.

In view of this quantum suppression of beamsstrahlung it may be useful to evaluate the machine parameters and the detector technologies of future high energy colliders, including the next linear collider. However, in this little article we concentrate on an even shorter bunch scheme of laser accelerators.

4.2.2 Laser Driven Accelerator

As seen from Eq. (4.3), an effective way to suppress beamsstrahlung is to reduce σ_z, for which laser acceleration [8] has easy time to satisfy, as it offers much shorter acceleration wavelength than that of conventional microwaves. For laser wakefield acceleration, a typical wavelength of accelerating wakefield is $\sim 100\,\mu$m, which is in the right range for the required bunch length in Table 1. Laser wakefield acceleration [9,10] has been an active area of research in recent years primarily due to the major technological advance in short pulse TW lasers (T^3, or Table-Top Terawatt lasers) [10]. The most recent experiment at RAL has demonstrated an acceleration gradient of 100 GV/m and produced beam-like properties with 10^7 accelerated electrons at $40\,\mathrm{MeV} \pm 10\%$ and a normalized emittance of $\varepsilon < 5\pi$ mm-mrad [11].

For beam parameters similar to that in Table 1, we consider a laser wakefield accelerator system consisting of multiple stages with a gradient of 10 GeV/m. With a plasma density of $10^{17}\,\mathrm{cm}^{-3}$, such a gradient can be produced in the linear regime with more or less existing T^3 laser, giving a plasma dephasing length of about 1 m [12]. If we assume a plasma channel tens of μm in width can be formed at a length equals to the dephasing length, we would have a 10 GeV acceleration module with an active length of 1 m.

Although a state-of-the-art T^3 laser, capable of generating sub-ps pulses with 10s of TW peak power and a few Js of energy per pulse [10], could almost serve the need for the required acceleration, the average power or the rep rate of a single unit is still quite low, and wall-plug efficiency inadequate. In addition, injection scheme and synchronization of laser and electron pulse from stage-to-stage to good accuracy have to be worked out. Yet another important consideration is how to generate and maintain the small beam emittance in the transverse focusing channel provided by plasma wakefield throughout the accelerator leading to the final focus. There are various sources causing emittance growth, multiple scattering [13], plasma fluctuations [14] and mismatching between stages, to name just a few. Should the issues of guiding, staging, controllability, emittance preservation, etc. be worked out, there is hope that wakefields excited in plasmas will have the necessary characteristics for particle acceleration to ultrahigh energies.

4.2.3 Accelerator Physics Issues of Laser Wakefield

We consider satisfying these collider requirements. As we have seen in Sec. 1, there are two important new guidelines for us to take. (a) The smaller the longitudinal size σ_z of a bunch of the electron (and positron) beams, the smaller the disruption parameter D_y, the amount of photons n_γ (and other secondary particle emissions), and the energy loss δ_E of the bunch due to the beamsstrahlung are, as seen in Eqs. (4.1) and (4.2). An alternative to make sure the last two numbers, i.e. n_γ and δ_E, are small, is to make the number of particles in a bunch N small. When we try to make N small in order to keep n_γ and δ_E small in accordance with Eq. (4.3), however, we have to make the frequency of bunch collisions f_c large and the size of the transverse beam size σ_y (and thus the beam emittance) small. The former requirement $f_c \propto N^{-1}$ (while n_γ, $\delta_E \propto N^{1/3}$) means that f_c has to be increased by a lot larger amount (K), when the N in Eq. (4.3) is reduced by a factor $1/K$. This sets a rather stringent constraint on accelerator considerations. The latter requirement also sets a rather stringent condition, as the emittance has to be reduced by a factor of $1/K$. A possible benefit of this strategy (reducing N) is to reduce the Υ parameter. (b) As we have seen in Sec. 1, we ought not to set $\Upsilon < 1$. In fact, when we set $\Upsilon \gg 1$, a large amount of quantum suppression occurs, as seen in Eq. (4.2).

Combining the above two findings (a) and (b), we adopt the strategy to reduce σ_z to satisfy Eq. (4.3) in $\Upsilon \gg 1$. To adopt smallest possible σ_z means to adopt smallest possible driver wavelength λ. In the following we list some of the important physical constraints for the wakefield acceleration for collider considerations.

The mechanism of the wakefield excitation and acceleration of electrons by this mechanism have been demonstrated by a series of recent experiments ([9], for example). What this approach promises is: (i) short driver wavelength of typically $100\,\mu$m (see below), at least two orders of magnitude shorter than the existing rf driver wavelength, and thus at least two orders of magnitude smaller σ_z than the competing linear collider equivalent (see, e.g. Wessenskow); (ii) the accelerating gradient far greater than any existing (or proposed) rf drivers by at least two orders of magnitude, thus leading to compactification of the accelerator at least by two orders of magnitude. The laser wakefield mechanism operates either in the linear regime or in the nonlinear regime. In the linear regime (as reviewed in [12]), the accelerating and focusing fields of the laser driven wakefields are

$$E_z = \mathcal{E}_0 \frac{\sqrt{\pi}}{2}\, a_0^2\, e^{-r^2/\sigma_r^2} k_p\sigma_z\, e^{-k_p^2\sigma_z^2/4} \cos(k_p\zeta), \tag{4.4}$$

$$E_r = -\mathcal{E}_0 \sqrt{\pi}\, a_0^2\, k_p\sigma_r\, \frac{r}{\sigma_r}\, e^{-r^2/\sigma_r^2} k_p\sigma_z\, e^{-k_p^2\sigma_z^2/4} \sin(k_p\zeta), \tag{4.5}$$

where $\zeta = z - ct$, $a_0 = eE_0/m\omega c$, E_0 is the laser electric field amplitude, and $\mathcal{E}_0 = m\omega_p c/e$. In the nonlinear regime stronger steepening (non-sinusoidal) wave profile as well as a higher wake amplitude is expected. In the linear regime the focused laser will diffract over the Rayleigh range $L_R = \pi w^2/\lambda_\ell$, where w is the focused waist size, λ_ℓ the laser wavelength. When there is a plasma fiber structure where the plasma density is depressed in the middle, the laser is expected to be contained much beyond the Rayleigh length [15], which has been demonstrated by Milchberg *et al.* [16]. When the laser is guided in such a plasma fiber, the acceleration is expected to last over the length shorter of the two, the dephasing length $L_{\rm dep}$ and the pump depletion length $L_{\rm pd}$, which are [8,12]

$$L_{\rm dep} \approx 2\omega^2 c/\omega_p^3 \propto n_e^{-3/2}, \tag{4.6}$$

and

$$L_{pd} \approx L_{\rm dep}/a_0^2. \tag{4.7}$$

In nonlinear regimes, however, the laser beam is expected to self-channel due to both the relativistic electron mass effect and the transverse wakefield space charge effect. The critical laser power above which this laser self-channeling takes place is theoretically given as

$$P > P_c = \frac{c}{4}\left(\frac{mc^2}{e}\right)^2 \left(\frac{\omega}{\omega_p}\right)^2 . \tag{4.8}$$

In recent years several experiments have demonstrated that self-channeling of laser happens above a certain threshold and in some experiments accompanying electron accelerations have been observed, though the mechanism and the threshold value are still in debate.

In the present collider design we take the laser wakefield excitation only in the linear regime with a (certain) external plasma channel formation (unspecified at this time). This is because we prefer a conservative, predictive, linear regime for collider operations. [On the other hand, for other applications of electron acceleration such as medical, a "carefree" nonlinear, self-channeling regime may be attractive.] The laser and plasma parameters we set for the laser wakefield accelerator operation are listed in Table 2.

The betatron oscillation length can be obtained from Eq. (4.5) through the focusing equation of motion as

$$y'' + \left(\frac{a_0^2 e\mathcal{E}_0 \sin(k_p\zeta)}{mc^2\gamma k_p\sigma_r^2}\, k_p\right)\sigma_z y = 0, \tag{4.9}$$

where σ_r, σ_z is the transverse and longitudinal and longitudinal sizes of the wakefield, k_p the wakefield wavenumber (c/ω_p). From this the betatron wavelength $\lambdabar_\beta$ is

$$\lambdabar_\beta = \left(\frac{mc^2\gamma\sigma_r^2}{a_0^2 e\mathcal{E}_0\sigma_z \sin\psi}\right)^{1/2}, \tag{4.10}$$

when $\cos\psi \equiv \cos k_p\zeta$, the phase factor of where the electron sits in the wakefield. We can show that the wakefield structure, Eqs. (4.4) and (4.5), has the quarter period of simultaneous focusing and acceleration, and at the same time this quarter period is the longitudinal focusing as well, a property distinct for laser wakefields and valuable for accelerator considerations. The associated electron (or position) beam size is given in terms of emittance ϵ as

$$\sigma_\perp = (\epsilon\lambdabar_\beta)^{1/2} = \left[\epsilon\sigma_r\left(\frac{\gamma mc^2}{a_0^2 e\mathcal{E}_0\sigma_z}\right)^{1/2}\right]^{1/2}. \tag{4.11}$$

It is instructive to check the interaction of beam electrons with the plasma particles. According to Montague and Schnell [13], the induced emittance growth due to the multiple scattering of electrons in a plasma is

$$\Delta\epsilon = \left(\sqrt{\gamma_f} - \sqrt{\gamma_i}\right)\cdot 4\pi r_e^2\sigma_0 n\left(\frac{mc^2}{e\mathcal{E}_0\sin\psi}\right)^{3/2}\left(\frac{-\pi\tan\psi}{\lambda_p}\right)^{1/2}\ell n\left(\frac{\lambda_p}{R}\right), \tag{4.12}$$

where γ_f and γ_i are the final and initial energy, r_e the classical electron radius, λ_p the wavelength of the wakefield, σ_0 the standard deviation of the laser cross-section. ψ the accelerating phase angle and R the effective Coulomb radius of protons. Our design parameters allow this emittance growth well within control. We point out, however, that the emittance growth due to the plasma fluctuations and the nonideal wakefield structure is very crucial in evaluating the current collider design, which has to be a very important future theoretical investigation. The energy loss due to the synchrotron emission in wakefield is estimated [13] to be

$$U' = 5\times 10^{-10}a^2\left(\frac{\gamma}{\beta}\right)^4, \quad (\mathrm{Vm}^{-1}), \tag{4.13}$$

where a is the betatron amplitude, while the particle cooling is

$$(U')_\sigma = 5\times 10^{-10}\gamma\epsilon\left(\frac{\gamma}{\beta}\right)^3, \ (\mathrm{Vm}^{-1}) \tag{4.14}$$

which is negligibly small for our parameters.

We briefly discuss the issue of beam loading. When we load multiple bunches behind a single laser pulse which is exciting multiple periods of wakefields, the energy gain by the different bunchlets arises due to the energy absorption (beam loading effect) of the wakefield by the preceding bunchlets. Since we want to increase the coupling coefficient between the laser energy to the beam energy, the laser-induced wakefield energy should be exploited to a maximal possible extent. It turns out that the increased coupling efficiency and the minimum spread (i.e. longitudinal emittance) of energy gain conflict with each other. According to Katsouleas *et al.* [17], the spread in energy gain in the wakefield is

$$\frac{\Delta\gamma_{\max} - \Delta\gamma_{\min}}{\Delta\gamma_{\max}} = \frac{N}{N_0}, \tag{4.15}$$

where $\Delta\gamma_{\rm max}$ is the maximum energy gain of a bunch, while $\Delta\gamma_{\rm min}$ is the minimum of a bunch, while the beam loading efficiency η_b (the ratio of the energy gained by the beam to the energy in the wakefield) is given by

$$\eta_b = \frac{N}{N_0}\left(2 - \frac{N}{N_0}\right), \tag{4.16}$$

where N is the total number of particles in a bunch and N_0 is the total number of particles at the perfect beam loading. The perfect beam loading is given [17] as

$$N_0 = 5 \times 10^5 \, \frac{n_1}{n_0} \, \sqrt{n_0} \, A, \tag{4.17}$$

where n_1 is the density perturbation of the wakefield [which can be expressed as a function of a_0^2, see Eq. (4.4)], n_0 is the background electron density, and A the area (in $\rm cm$) of the laser pulse (or wakefield). Because of this difficulty (though some optimization may be done with the shaping of the laser pulse), we adopt the strategy of having only one bunchlet per wakefield. Because of large Υ, significant quantum suppression takes place and n_γ and δ_E are independent of N in the extreme large Υ, we can put all particles in a single bunch (maximize N) to maximize the beam loading efficiency, without facing the consequence of Eq. (4.15). Thus the beam loading efficiency can be as large as near 100% (though we probably choose it around $\frac{1}{2}$, for the internal bunch structure consideration).

Some additional comments are due for the preferred operating scenarios of [1], Scenario IA and Scenario IB. Scenario IA represents the design that is in the large Υ regime, where the condition Eq. (4.3) is respected, though it is at the edge of entering the extreme large Υ regime. Here the energy constraint for the beam energy gain per stage requires that the laser beam area A is of the order of $10^{-6}\,\rm cm^2$, accelerating particles of $N \sim 10^8$. In this scenario, since the spot diameter of laser ($\sim 10\,\mu$m) is of the same order of the plasma collisionless skin depth, we recommend the use of the hollow plasma channel, in which (we do not specify how) the vacuum channel with width $\sim\ \mu$m surrounded by a plasma of $n_0 \sim 10^{17}\,\rm cm^{-3}$. Thus a small emittance requirement of Scenario IA might be met (though as we cautioned in the above, the plasma noise effects [14] need to be assessed). In this regime, required lasers are already available at the power etc., except for the high repetitive rate, although a gun barrel-like multiple lasers, for example, can be considered (see [10]).

An alternative scenario, Scenario IB, takes full advantage of the extreme high Υ regime. As we commented already, in this regime we need not respect Eq. (3) any more and once we choose σ_z and the related conditions in Eq. (15), we can arbitrarily set N as far as the collider considerations are concerned. As we metnioned in this section, we set N from the laser and plasma considerations and $N \sim 10^{10}$. In this scenario, Υ exceeds 10^4 and in a completely quantum regime. In such a high Υ regime we need further study of collision physics, however. The relatively large N allows relatively low laser repetition rate f_c, ($< 10^3$ Hz) relatively large emittance ($\epsilon \sim 100\,$nm) at a relatively low power (2 MW).

Lastly, it might alarm some of us to know that a large number of instabilities [18] exist in a plasma. To our best knowledge, however, we fail to see these parameters of beam-plasma particles give rise to damaging beam-plasma instabilities. This is firstly because the bunch length is shorter than the typical wavelength of the instability $2\pi c/\omega_p$. Secondly, the rigidity of beam at $\gamma \sim 10^6$ makes most of the plasma instability growth rate small.

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Table 4.2: Laser and Plasma Parameters for Case IA [1]

laser energy	$\frac{1}{3}$ J
pulse length	100 fs
plasma density	$10^{17}\,\mathrm{cm}^{-1}$
laser intensity	$10^{18.5}\,\mathrm{W/cm}^2$
spot size	$\sim 10\,\mu$m
power	10^{12} W
dephasing length	$10^2\,\mathrm{cm}$
pump depletion length	$10^2\,\mathrm{cm}$
$E_{\rm acc}$	10 GeV/m
$\frac{dE_{\rm acc}}{dr}$	$10\,\mathrm{GeV/m/(5\,\mu m)}$
plasma channel	hollow channel of $\sim 10\,\mu$m diameter
rep rate	50 kHz

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4.3 Beam Dynamics Issues in the Luminosity Upgrade at HERA

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4.3.1 Introduction and Physics Motivation

Plans are now underway at HERA to raise the luminosity nearly five-fold from the design value of $1.5\times10^{31}\mathrm{cm}^{-2}\mathrm{sec}^{-1}$ to $7.4\times10^{31}\mathrm{cm}^{-2}\mathrm{sec}^{-1}$. There is also an option under study to raise the top energy of the proton beam from 820GeV to 920GeV in the upgrade but the electron top energy will remain at 30GeV. Below we briefly review why increasing the luminosity is such a desirable goal and then discuss the beam dynamics issues involved.

HERA until now has been used primarily as a QCD machine to measure the proton structure function F_2 to an unprecedented accuracy of 5-10% in new kinematical regions. Electro-weak physics has been relatively little explored. Some of the electro-weak physics that can be done at higher luminosity are

- Measure the W mass to high accuracy. This would provide a good check of the Standard Model.
- Put limits on the mass of the Higgs particle.
- Check for anomalous W coupling - this would check the gauge property of the electro-weak theory.

An increase in luminosity will also provide more answers in QCD, including

- Better measurement and understanding of the proton structure functions.
- Distinction between the F_2 and F_3 structure functions.
- Spin dependent phenomena in QCD.

Higher luminosity will also create more high Q^2 events which would settle the question of whether there is new physics beyond the standard model (lepto-quark ?) or if the events seen until now are a statistical anomaly. QCD physics will also benefit somewhat if the proton energy is raised. At 900 GeV, the increase in production rate of the leptoquark (if it exists) would be around 20-30% for a leptoquark mass of 220 GeV at the present luminosity. The compelling argument for an energy increase is that the $b\bar{b}$ production rate rises, so that HERA-B would profit with an expected increase in cross-section of roughly 40% in the study of CP violating processes.

4.3.2 New Interaction Region(IR)

4.3.2.1 Lattice Design

The luminosity will be increased by squeezing both the protons and electrons to smaller spot sizes at the IPs. This requires stronger focusing by quadrupoles within the IRs. The quadrupoles focusing the 820GeV protons must not act on the electrons therefore the beams have to be separated early or else the 30GeV electrons will get strongly overfocused. At present the beams are separated at 28m. In the new design, superconducting combined function magnets placed within the detectors focus the electron beam and also separate the beams, much more quickly than at present, from the collision point. Beyond these superconducting magnets are warm quadrupoles centered on the electron orbit. They have a focusing action almost exclusively on the electrons but they do deflect the protons. By 11m, the beams are sufficiently separated that the first proton focusing quadrupoles can be placed. These are special types of half septum quadrupoles with V shaped notches in the mirror plates. The protons are vertically focused by the region of high field while the electrons go through the notch which is field free. Beyond these are current septum quadrupoles which complete the vertical focusing of the protons. A quadrupole doublet will be added after the current septum to focus the proton beam at the higher energy of 920GeV and also make matching into the injection optics easier. There will be no change in the rest of the magnets in the straight section. This layout of the magnets has enabled the proton β^*'s to be reduced from (7.0,0.7)m to (2.45,0.18)m while the β^*'s of the electrons have been reduced from (2.0,0.7)m to (0.63,0.26)m. The emittances and beta functions are such that both beams have the same transverse dimensions of (0.118,0.032)mm at the IP. Matched beam sizes minimize the effects of the beam-beam interaction on the luminosity and the lifetime. The optics is nearly symmetric about the IP for both beams. The shift in symmetry comes about because the magnets downstream of the IP must have transverse offsets to let the synchrotron radiation pass through.

4.3.2.2 Synchrotron Radiation

Strong synchrotron radiation is generated by the bends close to the IP and the critical detector components and the magnets have to be protected from this radiation. The total power radiated by the beam is 26kW at an energy of 30GeV and a current of 58mA. This radiation is required to pass through the detector with a clearance of at least 5mm from any detector component. Main absorbers placed downstream of the IP will absorb about 21kW of the power with the remaining 5kW passed on and absorbed further downstream. These absorbers will be made of copper and will be water cooled. The main source of synchrotron radiation background in the detectors comes from radiation backscattered from these main absorbers. Additional absorbers placed closer to the IP will be required to protect the detectors from the backscattered radiation. These absorbers in turn have to be protected from primary radiation generated in the upstream low-beta quadrupoles. This quadrupole radiation although of relatively low power ($\sim$ 360W) has a large divergence. The size of this quadrupole radiation fan will be reduced by transverse offsets in the low-beta quadrupoles and the radiation will be absorbed by specially placed collimators.

4.3.3 Beam Dynamics

4.3.3.1 Electron Dynamics

The upgrade will require many changes in the electron ring. The north and south insertions will be rebuilt with superconducting magnets and additional warm quadrupoles, and a pair of spin rotators will be added to each of these insertions. The beam will also be focused more strongly in the

FODO cells. These changes in the linear optics will significantly affect the non-linear behaviour of the e-beam.

Linear Optics At present HERA-e operates with a 60 degree phase advance per plane in the FODO cells and a horizontal equilibrium emittance of about 40nm-rad. Larger betatron phase advances are needed in order to reduce the emittance but the allowable increase is limited by the fact that the dynamic aperture will decrease as stronger sextupoles will be required to correct the higher chromaticity of cells with a larger phase advance. In the upgrade, the horizontal emittance will be lowered to 22 nm-rad by increasing only the horizontal phase advance per FODO cell to 90 degrees and keeping the vertical phase advance at 60 degrees. The vertical emittance will be determined by the expected emittance coupling ratio of 18%. The optics of the new IRs has been designed to keep their linear chromaticity nearly the same so the increase in the total chromaticity of the ring is contributed almost entirely by the arcs. The optics of the ring is also made spin transparent in order to minimize spin diffusion and maximize the polarization over time.

Since 1994 HERA has operated with positrons in the e-ring because operation with electrons suffered from a reduced lifetime due to trapping of heavy charged particles. It is believed that a major source of these particles are the integrated ion getter pumps which are presently installed. These will be replaced by non-evaporating getter (NEG) pumps during the winter shutdown this year. The remaining problems may be related to trapping of medium sized ions such as Argon which would be stable in the present HERA beam and which will not be pumped effectively by the NEG pumps. The stronger horizontal focusing in the arcs envisaged for the upgrade is expected to help in preventing these remaining particles from being trapped by the beam.

Chromaticity Correction and Dynamic Aperture The nonlinear chromaticity of the ring is dominated by the contribution of the IRs. Their contribution will be corrected by a local distribution of non-interleaved sextupoles placed in the arcs adjacent to the IRs. The linear chromaticity of the ring will be corrected by a single family of sextupoles in each plane placed in the rest of the arcs. This arrangement gives a significantly smaller chromatic variation of the tunes and the beta functions than the more conventional arrangement of interleaved 2 and 3 families of sextupoles in the horizontal and vertical plane respectively.

The dynamic aperture in the presence of the resultant sextupole nonlinearities and the closed orbit errors is acceptable over a momentum range of $8\sigma_p$. While the beta functions at the superconducting magnets within the IRs are not large, it is expected that multipolar field errors in these magnets will reduce the dynamic aperture somewhat. Further optimizations of the dynamic aperture are planned including placing sextupoles in the straight sections to compensate the third order resonances driven by the sextupoles in the arcs. Another possibility is not to increase the horizontal phase advance to 90 degrees but instead to an intermediate value between 60 and 90 degrees and increase the RF frequency by the required amount (a few hundred Hz) in order to reduce the horizontal emittance. This would lower the strengths of the sextupoles and improve the dynamic aperture for on-momentum particles at the expense of an increased momentum spread.

Beam-beam constraints During operation over the last year, the lifetime of the positron beam has typically been around 10-15 hours. At currents less than 40mA the lifetime is dominated by inelastic nuclear scattering with gases desorbed from the walls of the beampipe. The loss of lifetime due to the beam-beam interaction is thought to be small. In the upgrade design, the beam-beam tune spreads will increase from average values of (0.01,0.03) in the horizontal and vertical plane respectively to (0.027,0.041). These are close to the limits considered acceptable for e^+/e^- beams. However, over the past year positron beams have on occasion been operated close to these limiting values without any observable effects on their size, e.g. there has been no significant effect on the specific luminosity when the positron beam-beam tune spread increased. There are indications that synchro-betatron resonances driven by the nonlinearities of the beam-beam interaction and sextupoles cause a beam blow up of about 10% in present operation. The effects of these resonances should be reduced in the upgrade since the dispersion is lowered in the RF cavities in the new optics.

Polarization Until now HERA has operated with a pair of spin rotators placed in the east insertion to rotate the spin direction from the transverse to the longitudinal at the gas target in the HERMES experiment. The plans for the upgrade call for longitudinal polarization at the H1 and ZEUS detectors as well so additional pairs of spin rotators will be placed in the north and south insertions. In the present lattice anti-solenoids placed close to the experimental detectors correct for the coupling and the residual tilt of the periodic spin orbit vector $\hat{n}_0$ at the IP due to the solenoidal fields of the detectors. In the upgrade these anti-solenoids will be removed to make room for the superconducting magnets required for focusing the electrons. The coupling will be corrected by skew quadrupole corrector coils wound on the superconducting magnets. The distortions in the $\hat{n}_0$ axis at the IPs will be corrected by asymmetric settings of the vertical bends in the pairs of spin rotators. The effect of the overlapping fields of the solenoids and the superconducting magnets on the polarization requires special study and this is in progress. The beam-beam interaction might limit the maximum polarization that is achievable but the evidence for this is not yet clear.

Collective Effects The dominant collective effects in the electron ring are the transverse and longitudinal multi-bunch instabilities. The dipole modes which have the fastest growth rates are damped by a feedback system in all three dimensions. The feedback system has been designed to operate at the design intensity of 58mA which will be reached after the installation of additional RF cavities later this year. The changes in the beta functions within the cavities have been kept small in the upgrade design so there should be little effect on the growth rates. An area of concern is the power losses in the superconducting magnets due to wakefields of the electron bunches and these will only increase with the smaller bunch lengths in the 90 degree optics. The power losses are also enhanced by the presence of synchrotron radiation absorbers within this section. Reducing these losses might require an elliptical cross-section of the beam pipe, copper coating the inside of the beam pipe within the cold section, and also perhaps lengthening the bunch with a shift in the RF frequency accompanied by a horizontal phase advance less than 90 degrees.

4.3.3.2 Proton Dynamics

In the proton ring, only the focusing within the north and south insertions is increased as described previously. The vertical β^* of the protons is lowered to 18cm where it is comparable to the present proton rms bunch length ~ 15cm. The hour-glass effect reduces the luminosity at these values by 5%. During the period of beam storage, the bunch length increases, primarily due to intra-beam scattering. This would lead to a loss in the integrated luminosity. The bunch length will therefore be reduced and the momentum spread increased by an increase of the RF voltage from the present value of 0.32MV to 2.4MV which will also reduce the growth rates due to intra-beam scattering. Further gains in luminosity can be obtained only by squeezing the horizontal β^* of the protons.

Linear Optics and Dynamic Aperture Protons are injected at 40GeV and ramped to the top energy of 820GeV at present. Consequently the emittance at injection is about 20 times larger than at collision and the injection optics must provide enough aperture for the larger beam sizes. This is specially important in the new septum quadrupoles where the multipolar field errors are expected to be significant. The injection optics for the upgrade has been designed to ensure a minimum aperture of about 6.5σ in the IR magnets - about the same as at present. An additional complication with the proton optics is that the proton orbit changes considerably (about 6-8mm in the low-beta quadrupoles) as the electrons are ramped from 12GeV to 30GeV due to the changes in the magnets which separate the beams and focus the electrons. In order to provide an acceptable aperture for the protons, their β squeeze will be done in two stages: first to intermediate β^* values till the electrons are injected, ramped and brought to their collision optics and then second from these intermediate β^* values to the final values.

The increased focusing in the insertions increases the horizontal chromaticity by about 10% but leaves the vertical chromaticity nearly the same. This increase is easily compensated by the available sextupolar correction coils. Preliminary tracking results show that the dynamic aperture with the marginally increased sextupole strengths will be acceptable. Further tracking studies are in progress to confirm that there is sufficient dynamic aperture when the multipolar errors of the special magnetic septum and current septum quadrupoles are included.

Beam-beam constraints At present the beam-beam tune spreads are (0.0011,0.0003) and there is little indication that the proton beam is significantly affected by the beam-beam interaction. Lifetime of the proton beam with colliding beams is usually several hundred hours and the emittance growth is about 3% per hour. With the upgrade design, the beam-beam tune spreads will increase only slightly to (0.0017,0.0005) so the protons should still remain far from the beam-beam limit.

Collective Effects In the proton ring, the transverse head-tail instability during the ramp and transverse multi-bunch instabilities are the major collective effects. A transverse multi-bunch feedback system similar to the one in HERA-e but with a more sophisticated tune measurement system was installed in HERA-p last year. This has enabled the damping of multi-bunch instabilities within a few hundred turns and also an accurate measurement of the tunes during the ramp. Automated settings of the sextupole strengths correlated with the tune values are used to correct the chromaticity and damp the single bunch head-tail instability. There are some signs of a weak longitudinal instability but it could be related to hardware issues. At present, about 90mA of current is routinely stored in HERA-p compared to the design value of 140mA. It is expected that improvements in the injector chain will enable the design current to be reached.

4.3.4 New instrumentation and diagnostics

New monitors will be installed closer to the IPs so that the beams can be steered to maximize the luminosity. It is planned to use 4 button pickups spaced uniformly around the beam pipe circumference for each beam at a location about 1.7m upstream of the IP for that beam. The chief advantage of these pickups is that they present a very small impedance to the beam. The resolution required has to be better than the smallest beam size at the IPs, about 30μm. The signals from each set of 4 pickups will be time-gated to suppress the signals from the other beam.

An additional synchrotron light monitor will also be placed within the north and south insertions. Various options to measure the radiation are being examined. These include diverting the radiation out of the beampipe through a quartz window to a wavelength shifter which increases it to the visible region and directs it to a CCD camera. Another is to use the scheme presently used in DORIS, i.e. to extract a part of the radiation with parallel tungsten plates and measure the currents flowing from each plate due to photo-emission to obtain an intensity independent position recording. A third possibility is to place either a set of fine wires or a set of platinum resistance thermometers on the face of the main synchrotron radiation absorber and measure either the photocurrent or the temperature profile respectively in order to obtain the position of the radiation fan.

There are pros and cons associated with each method and further investigations are in progress to select one method from these.

4.3.5 Outlook

The present schedule calls for the upgrade to be completed in the winter of 1999-2000. HERA in the new millennium will be operating at significantly higher luminosities and with a greatly expanded physics reach. Future options that are being examined include colliding heavy ions with electrons, polarized protons at near TeV energies, and HERA-p as part of an $e-p$ collider with electrons at 500GeV from the linear collider TESLA. Further information about the HERA luminosity upgrade can be obtained at the website

`http://www.desy.de:8888/~herawww/lumiup/lumi.html.`

4.4 Beam Dynamics Activity at IHEP (Protvino)

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Mid-October 1997 marks 30th anniversary of commissioning IHEP's 70 GeV proton synchrotron U-70. For a few years — until the advent of FNAL Main Ring and CERN SPS — it has been the world largest. To this end, on October 14 IHEP's veterans and senior people in the field have met in Protvino to share with younger generation of accelerator physicists their nostalgic reminiscences of those early years of IHEP.

U-70 is maintained in operational shape and is now subjected to a gradual upgrade. A dedicated 2 week run in the end of November for machine development is foreseen. Corrugated vacuum chamber has been replaced with a smooth one. It has already nearly eliminated microwave instability at transition crossing. Hence, bunch evolution follows adiabatic law with a certain blow-up of longitudinal emittance at transition. Transient beam loading of RF cavities and other problems related to partial orbit filling by bunches are encountered and suspected to hamper, say, operation of feedbacks.

Modernization program to boost beam intensity of U-70 to $3{\cdot}10^{13}$ p.p.p. is being worked out. Lack of funding forces the staff to concentrate efforts on a few crucial topics which promise major gains — strip-foil H^- injection scheme, enhancement of chromaticity correction system to counteract transverse instability observed at a slow-extraction flat-top (it cannot be handled with the octupole correction only), better control system and feedback circuits, etc.

IHEP's 600 GeV UNK proton synchrotron Project is still continued, though at a lower pace.

Physical design study of feedback loops that would govern longitudinal motion (around PA to settle heavy transient beam loading, beam feedbacks for a fast phase correction via a quadrature voltage to damp injection errors, and a phase-frequency loop) is near completion. Special measures are foreseen to cope with adverse effects peculiar to large rings — small separation of rotation harmonics and strong signals due to partial orbit filling by bunches.

Liners to shield vacuum pump boxes were redesigned to ensure safer assembling, and their screening effect has been verified via bench testing.

Optics of the straight section where a hydrogen jet target is to be housed was revisited so as to correct and minimize effect of magnetic field of the NEPTUNE experimental set-up on the beam motion. HOMs of the closed conical volumes of the set-up were carefully inspected, HOM-dampers and tuners were inserted where necessary to avoid beam instabilities and excessive heat load due to excitation of parasitic modes by beam.

Within frames of IHEP–DESY Agreement, in 1997 a group of beam dynamics people from IHEP have been closely involved into a physical design study of a proposed 800 MeV Booster synchrotron for DESY–III PS (DESY, Hamburg). This job has offered local accelerator physics community an infrequent occasion to be engaged in a self-contained comprehensive study of a new machine.

To conclude, despite certain financial and manpower constraints, beam dynamics activity at IHEP is maintained, albeit with less efforts than before.

4.5 Beam Dynamics Activity on the UVSOR Storage Ring

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4.5.1 Introduction

The UVSOR electron storage ring at Okazaki was constructed 15 years ago as a typical 2nd generation light source and has been routinely operated to provide synchrotron radiation of mainly VUV wavelength region to more than 300 users. Since continuous and stable supply of the beam is given the first priority in the operation, more than 40 weeks per year are devoted to the users and there has been little chance to have a long shutdown period to improve the machine. Moreover, due to a lack of enough considerations in the construction of this machine, there are several unsatisfactory points, large misalignments of focusing magnets and many sudden discontinuities of beam pipes, for example. These prevent us from developing a competitive performance of SR and also from studying the machine and the beam.

Nevertheless some experimental works have been carried out for various issues such as Landau damping of the coupled-bunch instability with combined use of 3rd harmonic RF cavity, the beam dynamics in free electron laser oscillations, lengthening of the bunch interacting with the impedance of the beam pipe, and the short bunch production by employing a lattice with very low momentum compaction factor. These works were not directly related to the improvement of the machine as a SR source and were not necessarily welcomed by the SR users, because they normally dislike frequent changes of the environment in their own experiments. Consequently, the studies at the UVSOR described below are intended to accumulate valuable knowledge of the beam dynamics of circular accelerators to design machines next to the 3rd generation light sources.

4.5.2 Storage Ring Free Electron Laser (SRFEL)

Free electron laser oscillation in the UVSOR rings was achieved in 1992 and basic research on SRFEL in the visible and UV region has been continuously performed. Since the available length of the straight section in the ring is only 2.5 m, it is almost impossible to install a very long undulator for high FEL gain so that the performance of SRFEL exceeds that of the conventional lasers. Main purposes of the UVSOR-FEL are to achieve the highest possible performance of the SRFEL under the strongly restricted conditions and to experimentally study the dynamics of the FEL interaction, particularly the issue of longitudinal bunch heating versus FEL power density.

An optical klystron employing helical magnetic field for two 9-period undulator sections separated by a dispersive part was designed to reduce on-axis photon flux of higher harmonics in order to avoid a damage of the mirrors in the optical cavity. The world record of the shortest FEL wavelength of 239 nm was accomplished in 1996 by using the helical optical klystron and a 600 MeV beam.

The maximum average power of SRFEL has been predicted using so-called ”Renieri’s limit” [1], which is due to an equilibrium between the damping and the excitation of the beam energy due to the FEL interaction. However, we have expected that the scenario of the bunch-heating may be much more complicated. Because the FEL pulse is getting narrower due to many-time interaction with the bell-shape gain profile (probably equivalent to the electron distribution), called ”gain-narrowing”, the energy exchange between the FEL and the electrons must occur at the top of the electron population. Since the synchrotron frequency is much smaller than the revolution frequency (for the UVSOR, 14 kHz and 5.6 MHz, respectively), the electrons would be partly heated up, then the gain may drop faster than what one expects assuming a complete stochastic heating over the entire longitudinal phase space. Increasing rate of the beam energy spread versus the laser power was observed by measuring the bunch length and a temporal evolution of the FEL power , and an empirical relation for the output power in equilibrated state was derived as [2]

$$P_{FEL} = \eta 16\pi^2 (N + N_d)^2 \Delta\sigma_\gamma{}^2 \frac{S}{n}\frac{P_{SR}}{E}, \tag{4.18}$$

where η, N, N_d and $\Delta\sigma_\gamma$ are a mirror efficiency, the period number of an undulator, the interference order of the optical klystron and the additional energy spread of the electron bunch, respectively. The formula is written in terms of the total synchrotron radiation power P_{SR} instead of the synchrotron damping time so that the beam energy E appears. A parameter S/n denotes the saturation energy for one electron, which is defined as an integrated energy extracted from the electron until the gain falls down to the half of the initial gain. The level of the saturation energy was found to be constant at various beam currents, but much smaller than the estimate from Renieri’s limit by a factor of 3 - 4 (for instance, an experimental value on the UVSOR-FEL with a 500 MeV beam is $S/n \approx 200\ keV$, while $S/n \approx 700\ keV$ from Renieri’s limit). In the analysis of the data of the bunch lengthening, a potential-well distortion due to the impedance of the vacuum pipe was taken into account to derive the energy spread. Since the FEL oscillation is most likely disturbed by small mechanical vibration of mirrors and collective motion of the beam, accuracy of the result is, however, not sufficient. Further experiments will be arranged by improving the diagnostic system and the optical cavity.

4.5.3 Single-bunch instability in operations with positive and negative momentum compaction factor

A longitudinal phase space distorted by impedances on the vacuum chamber is a crucial problem for the FEL oscillation because the longitudinal gain profile is directly proportional to the electron distribution. Potential-well distortion due to the reactive part of the impedance normally causes the bunch lengthening then electron density is decreased. Moreover, anomalous momentum spread is provoked at the beam current above a certain threshold current (microwave instability). Our study on the longitudinal behavior of the single-bunch beam has been focused on systematics of dependence on magnitude and sign of momentum compaction factor α.

The energy spread has been derived from spontaneous spectrum from the optical klystron. Since jagged-structure of the spectrum due to the interference between two undulator radiation is very sensitive to the electron energy, finite dispersion of the electron energy leads incomplete interference in the spectrum. Figure 4.1 (a) and (b) show measured current dependence of the bunch length and the energy spread, respectively, for both positive and negative signs of α with almost the same magnitude. It is obvious from the data for a lower beam current that the bunch lengthens for $\alpha > 0$ and shortens for $\alpha < 0$, which is a clear evidence of that the inductive impedance dominates the bunch length. Then the wake field may be expressed as $V_{inductive} = -L(dI/dt)$. In the negative α operation, an onset of microwave instability, confirmed by the measurement of the energy spread, was found around 15 mA. On the other hand, although the threshold current of the microwave instability in the positive α operation is not clear in the data of the bunch length, one can see that the constancy of the energy spread is broken around 50 mA. Taking a combined accelerating fields of the RF and the inductive wake fields into account, rms bunch length σ_b at the beam current I below the microwave instability is analytically evaluated assuming a bell-shaped electron distribution as [3]

$$\left(\frac{\sigma_b}{\sigma_0}\right)^3 - \frac{\sigma_b}{\sigma_0} = \frac{e\alpha I \mid Z/n \mid_{eff}}{\sqrt{2\pi}{\nu_s}^2 E}\left(\frac{R}{\sigma_0}\right)^3, \tag{4.19}$$

where σ_0, ν_s, R and $\mid Z/n \mid_{eff}$ are the bunch length at the zero current, the synchrotron tune, the mean radius of the ring and the effective longitudinal coupling impedance.

Figure 4.1: (a) Measured rms bunch lengths at $\alpha = +0.035$ (●) and $\alpha = -0.033$ (○) normalized by the zero current value (130 ps). (b) Measured rms energy spreads at $\alpha = +0.035$ (●) and $\alpha = -0.033$ (○) normalized by the zero current value (0.21 MeV for 600 MeV beam). (c) Deduced inductive impedances from the bunch lengths for two different positive α as a function of the average frequency of the bunch shape.

Since the bunch shape contains wide-range frequency components, the average frequencies were derived as follows. We first obtain the frequency distribution of each measured point by applying Fourier transform to the bunch profile data taken by the streak camera and then averaged it. In Fig. 4.1(c), preliminary results of deduced effective impedances using the above formula are plotted as a function of the average frequencies for two different positive α operations. Regions guided by dashed lines include influence of the microwave instability. Excluding these regions, the inductive impedance seems to be constant $\sim 1.4\ \Omega$ in the frequency region up to 1.5 GHz. Absolute value of L is roughly estimate d to be $4 \times 10^{-8}\ H$. Considering that the circumference of the UVSOR ring is about 50 m, this value of L is approximately 10 times larger than that of newly constructed 3rd generation sources such as SPring-8, where the vacuum chambers have been designed to reduce the impedance. (It might be quite reasonable for the 15-year old machine.) The negative α operation showed us some attractive properties of the beam for the FEL operation. Although the threshold current for the microwave instability is rather low, the instability does not kill the beam and the peak current remains higher due to the bunch shortening than that in the positive α operation. If the growth rate of the energy spread due to the FEL interaction exceeds that of the microwave instability, the FEL oscillation would be operated in a stable regime with keeping higher gain than the positive α case. We are, at present, focusing on understanding the longitudinal beam dynamics. Further experiments including resistive part of the impedance by measuring the loss factor are under way. The author thanks Dr. M. Hosaka, Mr. J. Yamazaki and Mr. T. Kinoshita for their contribution throughout the studies. He also appreciates Dr. M-E. Couprie of LURE and Dr. D. Robin of ALS for valuable discussions.

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4.6 Beam Dynamics Activities at CLRC Daresbury Laboratory

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4.6.1 Introduction

The beam physics group at Daresbury is a small one but with wide responsibilities. The initial Daresbury accelerator was NINA, a 5 GeV electron synchrotron commissioned in 1966, but domestic high energy physics ended with its closure in 1977. Subsequently a 20 MV tandem allowed front line nuclear physics research but this was also terminated some time ago. As a result Daresbury now concentrates on one mainstream activity: synchrotron radiation sources based on electron storage rings.

The SRS, the 2 GeV UK national light source, was commissioned in 1980 and was the world's first such dedicated x-ray facility (often called a second generation source). In fact the SRS serves a community ranging from biologists and material scientists, requiring x-rays up to about 50 keV, all the way through to infra-red spectroscopists. The storage ring has had several upgrades during its lifetime, the most major being a substantial lattice modification in 1987 giving an emittance reduction of one order of magnitude (but still about 100 nm-rad, no longer world competitive into the next century). Further major layout changes accompanied the installation of a second (6 T) superconducting wiggler magnet in 1992, necessitating numerous component relocations and redesigns in order to provide space. Late next year the final such disruption is planned with the addition of two multipole wiggler sources: once again space restrictions force drastic solutions, this time the movement of the 500 MHz accelerating cavities and other equipment in 10 of the 16 straights .

In addition to SRS work, other interests of the team will be mentioned below. A feasibility study of a 3rd generation successor to the SRS, known as DIAMOND, has been completed. Assistance continues to be given under a consultancy agreement to Oxford Instruments on all compact source matters. Some 4th generation topics, such as FEL issues, are also pursued.

4.6.2 SRS Beam Studies

Experimental beam studies shifts on the SRS take place usually for a two day period each month. However priority must be given to maintaining efficient source operations for users and this typically occupies up to half of the time allocation. Of the remainder most is used for approved improvement projects with little available for more academic studies. However the SRS has seen dramatic performance enhancements, even over the last two years, and some examples will be discussed.

Much the largest effort has gone into orbit control, which is so vital to a successful light source. Typical uncorrected rms closed orbit errors in both planes are in the range 5-10 mm and can double in a period of around one year, due to quadrupole displacements that cannot be completely stabilised for reasons still not fully understood. In order to maintain correctors below saturation values a number of main lattice quadrupoles must be moved when necessary and a simulation exercise allows this to be carried out efficiently. A complication of this (and other) SRS experiments is that the storage ring schedule requires runs with two very distinct working points so that the closed orbit reoptimisation is a compromise solution.

The SRS is now refilled on a daily basis, with beam lifetime typically 30–50 hours in the range 150–250 mA. The uncorrected user orbit is seen to drift by several hundred microns over the 24 hour period and this must be overcome. Initially we developed a local vertical servo (LVS) correction based on photon beam monitors at user experimental positions; this has operated routinely to stabilise up to 6 beam lines simultaneously to a few microns residual movement. It is difficult to provide a horizontal photon monitor due to the wide radiation fan so that in this case we have run a global orbit correction scheme based on our micron resolution electron bpms. During the last year a more advanced SVD (single value decomposition) correction algorithm has replaced the earlier least squares analysis and this is now in routine use; we have extended this global scheme to include both electron and photon monitor data and this has been highly successful: 11 SRS beam lines are now routinely served to an accuracy of 1–2 μm rms over many hours. The SVD approach allows the system to ignore occasional missing monitors, for example when a beamline shutter is closed !

Injection to the SRS takes place at 600 MeV and the energy ramp takes about one minute. In the past orbit control during this ramp has been quite relaxed, but with the installation of reduced aperture MPW vessels now imminent it has been decided to servo control the closed orbit throughout the ramp. The beam-stay-clear will be reduced from 34 mm to 15 mm, an aggressive figure for a second generation light source that was established only after extensive simulations and experimental tests including lifetime and injection checks.

Another major concern has been to optimise the beam against profile instabilities. Ion trapping effects have always been observed, even with clearing electrodes minimising the problem, but these are almost completely removed (at least for 2 GeV user beams) by ensuring a gap is maintained in the circumferential fill. Such a gap also helps with Landau damping of coherent instabilities, but another project has been the assessment and minimisation of coupled bunch effects arising from HOMs in our accelerating cavities. We now control our cavity temperature more carefully as an effective countermeasure and we are planning a closed loop correction for the near future.

The SRS is scheduled for about 10 % of its operations in single bunch mode for time-resolved studies. Touschek lifetime limitation is overcome by change of working point and a deliberate coupling increase, achieving a current-lifetime product of about 300 mA-hours. Lifetime factors are being carefully assessed to identify the different contributions. Typical user beams are 30 mA but in beam studies periods we have exceeded 100 mA in a 600 MeV stack and 50 mA at 2 GeV is fairly readily available. This has allowed extensive investigations of bunch lengthening and chamber impedance, together with transverse mode tune shifts. Recently our attentions have shifted to the interesting issue of bunch purity: our users demand contamination in other buckets to be less than 10^{-3} and we have commissioned a high resolution photon counting system to monitor this. Already we have clear evidence of electron migration between buckets and we are undertaking experiments to explain this phenomenon.

It is amusing to note that whilst the quest is normally for high intensity we believe that the SRS has now set another record: for the lowest currents for *operational* usage (yes, even single electrons have been observed at Novosibirsk and perhaps elsewhere) ! In our case the demand is for stable currents of 100–1000 nA to allow space mission detectors to be calibrated. In the last example an initial 1 μA beam was maintained for the full six days of the user run, another SRS efficiency record !

We are continuing to investigate injection into the SRS. It is apparent that as in many other electron storage rings the process is not really in accord with the perhaps naive multi-turn betatron analysis, but includes a compromise involving both orbit excitation effects and off-energy particles. We hope to develop a more accurate model that will predict SRS performance and that of other rings, and to apply this to our DIAMOND study.

4.6.3 New Light Source Developments

The UK strategy for replacement light sources has seen much evolution in the last decade. Initially the group designed an intermediate energy source known as DAPS, based on a 1.3 GeV racetrack storage ring, but now priority is given to a higher energy (3 GeV) solution called DIAMOND. At present our reference design is a 16- cell DBA racetrack lattice with two superstraights and a comprehensive feasibility assessment of this was completed last year, including provisional resource estimates. We were helped in this by two visiting scientists from the Barcelona Light Source project on EU Fellowship grants. The project would include a full energy injector and we have been examining minimum circumference 3 GeV booster solutions. One feature of the lattice is the potential upgrade path of replacing a few of the main achromat dipoles by superconducting magnets. In parallel with these studies we also designed a lower energy source, SINBAD, as a dedicated VUV ring with racetrack straights allowing free electron laser exploitation.

A strong scientific case for DIAMOND has now been made and we are hoping that funding of the first stage comprehensive Design Study will be approved in the near future. Meanwhile we have started to reassess some of our assumptions, including the lattice choice and the RF system. So far our nonlinear optimisations have failed to produce dynamic aperture and momentum acceptance results as good as we had hoped; however we are now considering whether to move to higher than 2-fold lattice symmetry. DIAMOND is also planned to have many MPWs and their perturbing effect on the lattice is another active topic. There is increasing interest in the light source community in the role of superconducting RF technology, not only for economy reasons but also to minimise HOM induced instabilities, and we are forming our own conclusions on this.

Members of the beam physics group are also involved in the design, construction, testing and commissioning of various insertion devices. The SRS already has two superconducting wavelength shifters (5 T and 6 T) and a 100 mm period undulator. We completed the specification and design of the new MPWs which are now under construction and we have also worked on plans for an elliptical polarising undulator using permanent magnet technology. Calculation of radiation spectral properties for all of our existing and proposed sources is also our responsibility.

The beam physics team has continued its support to the development of compact light sources by Oxford Instruments; we completed beam physics designs of both HELIOS-1 and HELIOS-2, 700 MeV superconducting storage rings delivering high x-ray flux. This included some interesting nonlinear dynamics issues associated with the small bending radius, necessitating some lattice code modifications. HELIOS-1 has operated routinely for a number of years at the IBM East Fishkill Facility, now achieving an injected current of 870 mA, whilst HELIOS-2 has recently been commissioned with our assistance and will be dispatched to Singapore early in 1998. We are continuing to seek performance improvements in this commercial product: for example, the relative merits of 500 MHz and 55 MHz systems are being debated.

The team maintains an interest in 4th generation developments and we have been members of an EU storage ring FEL Network examining their potential. Our high single bunch currents and good experimental diagnostics make the SRS an ideal tool to study some high peak current features and we are exploring international collaborations on this. We are also keen to collaborate in proposed European initiatives to extend FEL operation to 200 nm or beyond.

4.6.4 Other Topics

Although most of our activities are devoted to light sources, and especially to electron storage rings, we do have other more general accelerator interests. Recently we have been looking at the potential of Compton scattering sources for x-ray generation based on quite low energy electron beams. It is not yet clear how competitive such a source could be but we might proceed to some experimental tests.

A quite different initiative is our collaboration with the Douglas Cyclotron Laboratory at Clatterbridge to assess a possible energy booster for the 60 MeV protons. This has also involved interaction both with CERN staff and the TERA projects as we try to determine whether the cyclotron beam can be successfully matched into a linac stage. Already some progress has been achieved in a preliminary demonstration that the cyclotron can be pulsed in order to conform more closely to the linac duty cycle. Our next step is to undertake diagnostics on the proton beam emittance and energy spread.

In 1994 Daresbury Laboratory was merged with the Rutherford Appleton Laboratory (RAL) and in 1995 we became an independent organisation with the two centres now known collectively as CLRC (Central Laboratory of the Research Councils). This has led to closer links between accelerator experts and some involvement by members of the Daresbury team in RAL based studies of high current proton accelerators. However the demand for synchrotron radiation appears to be insatiable and most of our efforts will continue to be devoted towards modern light source developments.

4.7 Beam Dynamics Activities at the Brazilian Synchrotron Light Source

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The Brazilian synchrotron light source (LNLS), based on a 1.37 GeV electron storage ring, is operating routinely with external users since last July. The commissioning period of about one and a half year was completed with the accumulation of 170 mA at low injection energy (120 MeV) and ramping of more than 100 mA to 1.37 GeV with 7 hours lifetime. During this first period of routine operation, one day per week is scheduled to machine studies (the day after maintenance, so a fraction of time is spent to start the machine up again). We did a series of measurements using an optical beam profile monitor that uses visible bending magnet radiation to form an image of the electron beam on a CCD sensor. We started by measuring the transverse beam sizes and, as a result, the horizontal and vertical beam emittances. A large coupling can be observed at injection energy (120 MeV) and we are investigating the possible causes for it.

We have also installed a high frame rate CCD camera (400 Hz) to observe phenomena with characteristic times of a few milliseconds, such as the betatron damping times. These damping times were measured by applying an horizontal excitation to the beam and observing the amplitude of the oscillation as a function of time. During these measurements we noticed some ’strange’ patterns for the beam image, depending on various parameters such as beam current, kick amplitude, RF gap voltage and operation point. We realized that some of the beam image features were associated with coupling and non-linear resonance effects, since the image can be interpreted as the projection of the phase space geometry on the coordinate axis at the observation point. We set out, then, a program to explore this technique of observing the beam image integrated over some milliseconds after an excitation, to experimentally study the dynamics of the transverse beam motion in the LNLS ring. We started by looking at the coupling resonance $\nu_x - \nu_y = 3$ excited by skew quadrupoles and the third integer resonance $3 \cdot \nu_x = 16$ excited by sextupoles. An extra sextupole in a high beta dispersion free section has been installed for this purpose and a pair of skew quadrupoles is already available.

Figure 4.2 shows two examples of images obtained when an horizontal excitation is applied to the beam under the action of a coupling field generated by a pair of skew quadrupoles. The images correspond to two operation points, below and above the coupling resonance $\nu_x - \nu_y = 3$. The two cases were also simulated by numerical tracking using the program MAD with a detailed model for the ring. It is possible to define a parallelogram circumscribed to the image which is formed after many turns of the bunches in the ring. The geometrical properties of this parallelogram contain information on the coupling coefficient and can be calculated analytically using the Hamiltonian formalism to describe linearly coupled motion near the coupling resonance.

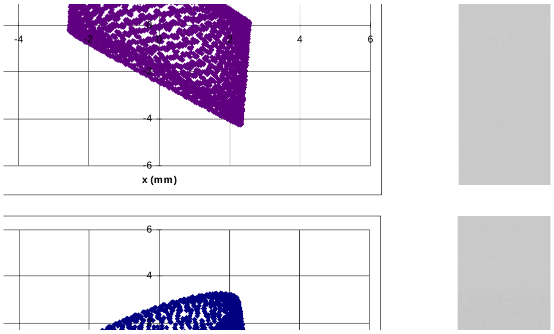
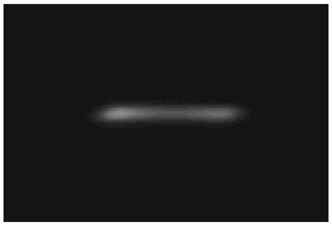
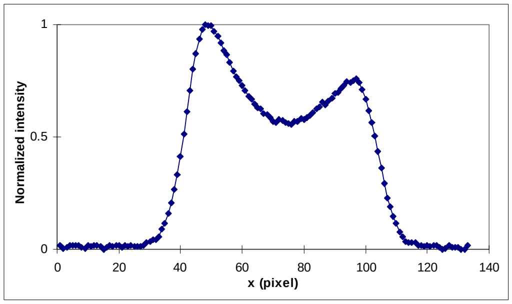


Figure 4.2: Measured beam image after 8 ms CCD integration time (right) and bidimensional map for the beam position (x and y, one division is 2mm) obtained by numerical tracking (left) on both sides of the linear coupling resonance. Top: $\nu_x = 5.07$, $\nu_y = 2.17$. Bottom: $\nu_x = 5.27$, $\nu_y = 2.17$.

Figure 4.3 shows the image and beam profile obtained when the beam is excited near the third integer resonance $3 \cdot \nu_x = 16$ under the action of a sextupolar field. The asymmetry of the peaks can be predicted theoretically using Hamiltonian resonance theory. All the expected asymmetry inversions caused by changing the sign of the sextupole gradient or by moving the tune from one side of the resonance to the other, were observed experimentally.

We have also observed features in the images which appear under certain conditions and are not yet understood. In particular, two extra peaks can appear (we call it the ’cocuruto’ – a Portuguese slang meaning hump – effect) when the beam is excited depending on the current, rf gap voltage and operation point. For fixed values of the two last parameters, the extra peaks appear suddenly at the center of the image at a certain current threshold and move away monotonically as the beam




Normalized intensity
1
0.5
0
0
20
40
60
80
100
120
140
x (pixel)

current decreases. At a certain current these extra peaks meet the 'normal' peaks, which are fixed for the same kick amplitude, and we get again the expected image for a beam undergoing coherent harmonic oscillation.

The results of these recently conducted experiments encouraged us to continue a research project in beam dynamics using the technique described. Another project within the group for the next months is to set up a bunch length measurement system using a fast (7 ps FWHM) commercial photodiode.

Measured beam image and profile near the third order resonance. The asymmetry of the peaks can be clearly seen.

4.8 Beam Dynamics at CERN

Other beam dynamics activities at CERN were described in the previous newsletter.

4.8.1 LEP

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During the 1997 run, which ended on 8 November, LEP was operated mainly at 91.5 GeV per beam with short spells at some lower energies requested by the experiments. As in 1996, most of the operation period was spent running the well-tested optics with $(\mu_x, \mu_y) = (90^\circ, 60^\circ)$ in the arc cells.

Performance for physics was very good with the beam-beam strength parameter, ξ_y reaching 0.056 and regularly exceeding 0.05. The experience at LEP is certainly consistent with a beam-beam limit rising with energy. However it is not clear to what extent this is due to improvements in machine tuning (e.g., reduction of residual vertical dispersion) that accumulate from year to year and within a given year of operation. If so, then the underlying energy-dependence may be rather weak. Some incline to the latter view.

For most of the year, total beam currents were limited by HOM losses, heating and vacuum effects, not beam dynamical effects.

The key to high luminosity is the vertical beam size and beam-separation scans have confirmed the luminosity data, showing that very small vertical emittances, of order 0.2 nm, are achieved.

In the April newsletter `http://www.indiana.edu/~icfa/icfa13/icfa13cern2.html` I mentioned our concern that the horizontal dynamic aperture of this optics would be insufficient at energies much beyond 90 GeV (if the emittance were allowed to increase with the square of the energy). We worry less about this now for two reasons:

1. To maximise luminosity, the horizontal emittance is now regularly reduced by increasing the damping partition number, J_x.
2. The traditional "beam-stay-clear" of 10 "sigmas" within the dynamic aperture has proved to be rather conservative. (And so it should have!) However it all depends on the mechanisms which transport particles to intermediate and large amplitudes and stronger criteria may have to be applied for other optics. Phenomenologically, it seems to make more sense to simply discuss the maximum usable emittance in a given configuration than to relate it to the dynamic aperture in any simple way.

With adjustment of J_x, the $(90^\circ, 60^\circ)$ lattice can indeed provide the optimum emittance for maximum luminosity throughout most of the range of energies and beam currents expected in future operation. Yet one powerful motivation for a lower emittance lattice remains: for a given total

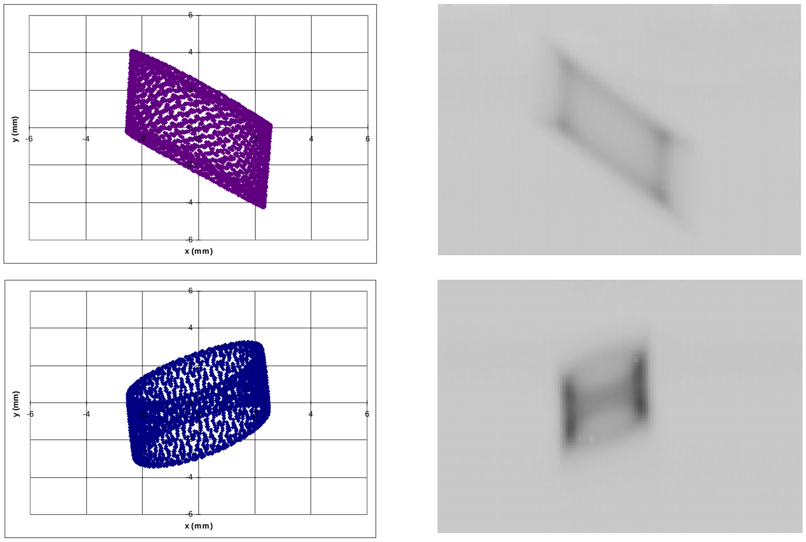

Figure 4.4: Integrated bidimensional beam profiles obtained by numerical tracking (left) and by measurement (right) on both sides of the linear coupling resonance.

RF voltage, V_{RF}, a lower emittance optics can reach higher in energy, the more so as increasing J_x has a price in V_{RF}. Perhaps it would be more appropriate to speak of *low-momentum compaction* lattices.

Among these, the $(108°, 90°)$ optics, tried with some success at 86 GeV in 1996, has been studied briefly in recent machine development time. As before, it was found to suffer from enhanced beam tails and sporadic losses at 46 GeV. These are clearly related to the strong detuning with horizontal amplitude bringing particles in the beam tail on to a nonlinear resonance $3Q_x = p$. Some progress was made in compensating the resonance with the help of measurements of kicked beams. However at 91.5 GeV, the beam tails were very clean and the situation improved without any special measures being taken. With some variation of damping partition, the range of emittances and energy spreads needed to operate up to 100 GeV looks accessible. One remaining question is whether there is an intrinsic reason why the *vertical* beam size should be larger, as it was in physics conditions last year, or whether it will come down with operational tuning as in other optics.

An intermediate optics, with $(\mu_x, \mu_y) = (102°, 90°)$ was tested in normal operational conditions for several days at the end of the 1997 run. The lower horizontal phase advance reduces the detuning with amplitude somewhat so the $3Q_x = p$ resonance is pushed to a higher amplitude. This test was very successful and luminosity performance approached that of the $(90°, 60°)$ lattice.

Transverse polarization of a few percent, important for calibrating the machine energy, has been obtained at energies above 46 GeV. A variety of other phenomena, e.g., bunch-lengthening, coherent damping, feedback systems and head-tail modes, have been studied experimentally. Theoretical and simulation work continues on topics such as single-particle dynamics with radiation and 3D collective effects.

During the winter shutdown, a further 32 RF cavities will be installed and the energy of LEP will be increased again in 1998. Attention will also be focused on raising the beam current limits.

4.9 Beam Dynamics Activities at UCLA

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University of California, Los Angeles

Recent beam dynamics work at UCLA in the Department of Physics and Astronomy can be classified in four categories: the physics of space-charge dominated, strongly accelerating beams, beam-plasma interaction, self-amplified, and spontaneous emission free-electron lasers (SASE FELs). In the summary of these activities given below, references to individual publications are given as they arise; all of the recent publications from the UCLA Particle Beam Physics Laboratory, which is jointly run by Profs. C. Pellegrini and J. Rosenzweig, can be found in PDF from on the WWW at

`http://pbpl.physics.ucla.edu/papers/`.

Recent papers appearing in archival journals are also listed in the bibliography.

4.9.1 Physics of Space-charge Dominated, Strongly Accelerating Beams

The physics of space-charge dominated, strongly accelerating beams has been studied at UCLA intensively due to our experimental development of rf photoinjectors for FEL and beam-plasma interaction experiments. The dynamics of beams in these devices are very complex, and so we have put considerable theoretical and computational work into understanding them. Of particular note is the development of an analytical theory of emittance compensation in photoinjectors [1], in which the process of compensation is understood in terms of the cold-plasma behavior of the beam's transverse motion. This theoretical treatment is based on the rms envelope equations in strongly accelerating systems, and utilizes a critical previous analytical theory of alternating gradient focusing in high-gradient linacs [2], which was recently demonstrated experimentally in the Saturnus Laboratory [3].

The theory of emittance compensation has been employed to design an optimized S-band 11.5 cell integrated plane-wave trnasformer rf gun/linac, which, when properly scaled in charge and wavelength (`http://pbpl .physics.ucla.edu/papers/JR1.pdf`) to X-band operation, has been simulated to give an unprecedentedly high beam brightness (`http://pbpl.physics.ucla.edu/papers/integ.pdf`). The S-band version of this devcie is under construction by a DULY Research/UCLA collaboration; the X-band photoinjector has been proposed as an ultra-high-brightness upgrade to the NLCTA injector.

The methods and concepts of the analytical theory of emittance compensation in axisymmetric beams has also been extended to beams which are highly asymmetric in transverse beam size and emittance (`http://pbpl.physics.ucla.edu/papers/JR1.pdf`). An asymmetric emittance compensated rf photoinjector may be used to inject into a relatively high charge, high emittance linear collider such as TESLA.

The Saturrnus laboratory produced many results in the area of beam diganostic development, which have proven critical in our understanding of space-charge dominated beam dynamics. Notable areas of success include development of a slit-based emittance measurement system (`http://pbpl .physics.ucla.edu/papers/emitslit.pdf`), and picosecond bunch length measurement using coherent transition radiation (CTR) interferometry (`http://pbpl.physics.ucla.edu/papers/ctr_paper_next.pdf`).

The Saturnus Laboratory has been decommissioned, with the majority of its components now being integrated into the new Neptune Laboratory, which is a collaborative effort with Prof. C. Joshi of the UCLA Electrical Engineering Dept. The photoinjector is being upgraded to have more powerful tools for beam manipulation and diagnosis (`http://pbpl.physics.ucla.edu/papers/Nep2N.pdf`). The most notable of these upgrades is the chicane compressor, which can produce ultra-short low charge beams for acceleration in plasma, and short pulse, high current beams for driving plasma wakefields (`http://pbpl.physics.ucla.edu/papers/compress.pdf`).

4.9.2 Accceleration and Focusing of Beams in Plasma

Our activities in the area of beam-plasma interaction are centered on development of the so-called blow-out regime of the plasma wake-field accelerator [4]. In this regime, the driving electron beam is denser than the plasma. The plasma electrons are quickly expelled, leaving a uniform ion density, electron depleted cavity , which has linear focusing for both the driver and the accelerating beam, and rf linac-like accelerating fields.

The high current, short pulse drive beam in this scheme must have a low enough emittance to self-guide in these induced ion-focusing fields. Recent experiments performed by a UCLA/ANL colllaboration at the Argonne Wake-field Accelerator showed this matched guiding with psec resolution measurements of the drive beam (2.3 times the density of the plasma) at the end of a long plasma section [5]. With this demonstration of the drive beam physics in hand, we are now pursuing 50-100 MeV/m acceleration experiments using a witness beam.

A straw-man conceptual design of a TeV collider based on this concept, using a large number of modules driven by a single heavily beam-loaded linac, has been explored (`http://pbpl.physics.ucla.edu/papers/NPWFA_Strawman.pdf`). The scaling of the beam and plasma dynamics with rf and plasma wavelength is also explored in this paper, as are future plans to perform two-stage acceleration experiments.

4.9.3 Self-amplified, Spontaneous Emission Free-Electron Lasers

The UCLA group has vigorously pursued the development of SASE FELS, which are a promising scheme for obtaining ultra-high brightness coherent x-rays. In addition to electron beam source development discussed above, we have performed two proof-of-principle experiments on the startup and gain processes in these devices.

The first of these experiments was performed at the Saturnus Laboratory with a 14 MeV beam, using a 60 cm long, 40 period high field undulator constructed by KIAE-Moscow. These experiments demonstrated one order of magnitude of gain, and allowed a detailed study of the fluctuations in output power [6].

In the second experiment, a 2 m, 2.06 cm period, equalized horizontal and vertical focusing undulator constructed at UCLA in collaboration with KIAE was transported to LANL and placed in the L-band photoinjector beamline. Ultra-high gain, with an initial estimation in excess of 10^5, was measured in this experiment, with data presently being analyzed. Coherent transition radiation at the FEL fundamental wavelength was observed emanating from the rear of a metal foil at the undulator exit, a clear indication of beam microbunching (`http://pbpl.physics.ucla.edu/papers/JR3.pdf`), which is the basis of FEL gain. Both FEL and CTR experiments will be resumed in December 1997.

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4.10 Space-Charge-Dominated Beam Dynamics at GSI

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The high-current beam dynamics group at GSI studies phenomena at high intensities and phase space densities (below transition energy) with the near-term goal of improving the performance of the heavy ion synchrotron SIS and the storage ring ESR; the long-term application of these studies is the use of heavy ion accelerators as drivers in inertial confinement fusion [1]. This goal is closely connected with a research program in plasma physics, where ”dense plasmas” are produced by focusing heavy ion beams of highest possible phase space density on solid density targets.

4.10.1 Nonlinear Effects in the Longitudinal Resistive Instability of Cooled Beams

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During storage of high currents with low momentum spread beams are subject to the longitudinal instability if a resistive impedance component is present at some multiple of the revolution frequency. The problem was studied experimentally years ago in the ISR (and other machines) to check if theory was right (see B. Zotter, *ICFA Beam Dynamics News Letter* No. 14, p. 9). These earlier measurements were made above transition energy, where the space charge impedance is negligible. We have investigated this mode in the space charge dominated regime, where we expect some interesting and yet unexplored features, mainly in the non-linear regime.

The ESR storage ring with electron cooling allows to carry out such experiments in the vicinity as well as far away from the stability boundary. Thus nonlinear saturation phenomena can be studied in the unstable region and compared with the findings from computer simulation. We first applied electron cooling to a C^{6+} beam at 250 MeV/u and 0.3 mA current in order to obtain a very small longitudinal momentum spread near 10^{-5}. The frequency of the r.f. cavity was then shifted from an initially strongly de-tuned value towards the beam revolution frequency to obtain the expected unstable behaviour. Subsequent time traces were recorded synchronously with the revolution period (waterfall diagram of Fig. 4.4). The diagram shows the initially exponential growth of the slow wave (moving to the right, since time is increasing from bottom to top), nonlinear saturation and decay into a fast wave moving to the left. The self-bunching effect was generally not exceeding 50% of the coasting beam current, which was found to be in excellent agreement with computer simulation. An interesting nonlinear effect is the appearance of significantly higher harmonic signals at some later time (0.2 seconds in Fig.4.4), which were not present if the instability on the fundamental harmonic was absent. We assume this results from a loss of Landau damping in the filamented phase space distribution of the saturated instability. It is also worth noting that the strong coherent signals persist for a long time. This is in contrast with the simplifying argument which predicts Landau damping due to an overshoot of the momentum spread after the instability has ocurred. These phenomena will be studied further.

Figure 4.6: Exponential growth and nonlinear saturation phase of longitudinal resistive instability of cooled coasting beam in the ESR driven by the r.f. cavity on the first harmonic. The waterfall plot shows subsequent time traces from bottom to top over 350 ms (each trace is the current profile over 2 revolution periods).

4.10.2 Space Charge in Multi-turn Injection

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Using the 2D particle-in-cell code SCOP-XY we have found that space charge in transverse multiturn injection leads to some interesting nonlinear effects. In connection with heavy ion fusion storage rings it is of interest to study simultaneous injection into the horizontal and vertical phase space by using a corner septum and bumping the equilibrium orbit away from the injection septum in both planes. Such a scheme has been calculated for a working point of Q_h=8.78 and Q_v=8.66 as shown in Fig. 4.5. The method is found to allow 15 turns of injection without any loss on the septum if space charge is ignored. In this case the center of the phase space distributions (in x,x' and y,y') is void. The choice of the working point in the tune diagram must be re-optimized for high space charge, hence for the corrected working point the injection loss at low current is expected to be bigger than with full space charge. The intrinsic incoherent space charge tune shift of the injected beam is 0.03. Calculations including space charge show that the nonlinear space charge forces lead to spiraling structures in phase space and some kind of halo. On the other hand, the center of the phase space distributions is filled quite densely. The halo is the reason why septum losses can be as large as 10%. The finally achieved coasting beam tune shift is about 0.05. An extension of this study to full 3D simulation (including the linac bunch structure) is under way.

Figure 4.7: Two-plane multi-turn injection scheme (20 turns) with corner septum in x-y plane. The upper frame shows the initial and final position of the septum due to the orbit bump in y. The working point has been optimized for without (left) and with space charge (right).

4.10.3 Emittance Measurement by Quadrupolar Oscillations

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For high-intensity heavy ion beams a non-destructive method of determining the incoherent tune shift and thus the emittance is of interest. We have implemented in the SIS a method which was for the first time studied recently at LEAR [2]. In this method (already proposed by Hardt [3]) the coherent space charge tune shift of quadrupolar oscillations is used to determine the incoherent tune shift.

The beam is excited with a signal sweeping over the envelope oscillation frequencies which are slightly shifted from $2Q_{h,v}$ due to space charge. The response signal on a quadrupolar pick-up consisting of four strip-lines is Fourier analyzed. There is a theoretical relation between the thus measured coherent frequency shift and the incoherent tune shift, which can be written approximately as

$$Q_{coh,1} - 2Q_{0,x} = -(3 - a_x/(a_x + a_y))\Delta Q_{inc,x}/2 \tag{4.20}$$

A second coherent frequency $Q_{coh,2}$ is obtained by simply interchanging x and y. $Q_{0,x}$, $Q_{0,y}$ are obtained from the signals in the low-current limit. The relationship can be used to determine in each plane the incoherent shift and thus the rms emittances. First successful measurements at the SIS for the horizontal tune shift of a coasting Ne^{10+} beam at the injection flat-top have been carried out. The thus determined ΔQ_{inc} was used to determine the rms emittance (see Fig. 4.6 where different side bands of these coherent lines are shown).

Figure 4.8: Measured space charge shift of quadrupolar (envelope) oscillation frequency in the SIS (dashed curve no space charge effect)

The method is presently refined by using computer simulation with SCOP-XY to determine the geometry factors applying to different beam density profiles.

4.10.4 Space Charge Effects on Multipole Oscillations and Anisotropy

The effect of space charge on higher order beam oscillations is of interest with respect to nonlinear resonances in circular machines and the subject of ”equipartitioning” in intense proton linacs. We have derived a self-consistent analytical theory to calculate the coherent tune shift of beams with different oscillation energies in two degrees of freedom (”anisotropic beams”) [4]. Based on the coupled Vlasov and Poisson equations we have obtained the dispersion relations of multipole oscillations of quadrupolar, sextupolar and octupolar symmetry. Numerical results applied to anisotropic (”non-equipartitioned”) linac beams show that such beams can be stable in spite of considerable anisotropy. Only for space charge tune depressions considerably stronger than is usually the case in high-current linacs the theory predicts instability of sextupolar or octupolar modes. The expected consequence would be an exchange of the oscillation energy and a full or partial removal of the anisotropy.

We are presently using 2D and 3D particle-in-cell simulation to explore the practical consequences of such anisotropy effects with respect to high-current linacs. Another potential application is longitudinal laser cooling of bunched beams [5]. There it is of interest to explore the possibilities of indirectly cooling the transverse degrees of freedom as a result of this energy exchange.

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4.11 New Doctoral Theses in Beam Dynamics

4.11.1 Vadim Sajaev

Author: Vadim Sajaev (`sajaev@inp.nsk.su`), BINP.

Institution: Budker Institute of Nuclear Physics, Novosibirsk, Russia.

Title: Dynamic aperture of accelerators with high chromaticity: theory and experiment” (in Russian).

Date: May 21, 1997.

Supervisor: Prof. G.Kulipanov (`kulipanov@inp.nsk.su`), BINP
and Dr. V.Korchuganov (`korchuganov@inp.nsk.su`), BINP.

Abstract: Single particle dynamics using azimuthal harmonic expansion of the sextupole Hamiltonian is discussed. It is shown that the essential features of the nonlinear motion (invariant curves, amplitude dependent tune shift, etc) can be described taking into account only few main harmonics. Horizontal dynamic aperture is studied analytically using single harmonic approximation.

Phase space near resonances $3Q_x = 26$ and $4Qx = 35$ is studied experimentally at VEPP-4M using fast kick and turn-by-turn measurements of beam position. The measurement of nonlinear detuning depending on working point allows to distinguish contributions of regular sextupoles and octupole perturbations to the detuning. The dynamic aperture of VEPP-4M is measured analyzing fast losses (20-100 turns) after kick. Horizontal dynamic aperture is increased by factor 1.5 after changing sextupole scheme.

4.11.2 Alexei V. Fedotov

Author: Alexei V. Fedotov (`fedotov@quark.umd.edu`), University of Maryland at College Park(UMCP).

Institution: UMCP

Title: Longitudinal Coupling Impedance of a Hole in an Accelerator Beam Pipe at Finite Frequencies.

Date: July, 1997.

Supervisor: Prof. R.L. Gluckstern (`rlg@quark.umd.edu`), UMCP.

Abstract: In much of the early work the hole dimensions were considered to be very small compared to the wavelength, which permitted the use of the static approximation for the fields. The main purpose of this work is to extend the analyses to include the effects of finite frequencies, including the possibility of resonant effects in the hole. The frequency corrections are important for long slots since the static approximation loses its validity when the length of the slot becomes comparable with the wavelengths contained in the beam spectrum. We develop the analysis and find frequency corrections for the coupling impedance of circular, elliptical and rectangular hole in the wall of a beam pipe.

4.11.3 Angelika Drees

Author: Angelika Drees (`Angelika.Drees@cern.ch`), the Bergische Universität und Gesamthochschule (BUGH) Wuppertal, 42097 Wuppertal, Germany

Institution: BUGH.

Title: High Precision Measurements of the LEP Center-of-Mass Energies during the 1993 and 1995 Z Resonance Scans.

Date: June 6th, 1997.

Supervisor: Dr. Karl-Heinz Becks (`BECKS@WPCL1.PHYSIK.UNI-WUPPERTAL.DE`), BUGH Wuppertal, 42097 Wuppertal, Germany.

Reference WUB-DIS 97-5.

Abstract: The calibration of the LEP beam energy is a substantial part of the determination of the Z mass and Z width. In principle, the LEP beam energy can be determined with a high precision of 200 keV using the technique of resonant depolarisation. However, the use of this technique is restricted to accelerator conditions without colliding beams, typically only at the end of a physics fill. In order to follow the evolution of the energy throughout a fill, a model, which will provide the instantaneous energy based on a set of corrections, is needed. The development of this model as well as the elaboration of the corrections during the 1993 and 1995 Z resonance scan will be described. In particular, the progress made in the 1995 scan compared to the model used in 1993 is presented. This progress is mainly based on the larger fraction of calibrated fills, energy calibrations at the beginning of physics fills and on an improved instrumentation to monitor the LEP dipole field in 1995.

4.11.4 Sameen A. Khan

Author: Sameen A. Khan (`khan@imsc.ernet.in`), The Institute of Mathematical Sciences, C.I.T. Campus, Tharamani, Chennai (Madras) - 600 113, INDIA
and
Dipartimento di Fisica Galileo Galilei
Dell'Universita di Padova
INFN Sezione di Padova, as a post-doctoral fellow.

Institution: University of Madras, Chennai

Title: Quantum Theory of Charged-Particle Beam Optics.

Date: September 1997.

Supervisor: R. Jagannathan (`jagan@imsc.ernet.in`).

Abstract: Quantum mechanics of the optics of charged-particle beams transported through an electromagnetic lens or other such optical systems is analyzed, using essentially an algebraic approach, starting *ab initio* from the basic equations (Schrödinger, Klein-Gordon and Dirac) of quantum mechanics. The underlying powerful algebraic machinery of the formalism makes it possible to do computations to any degree of accuracy in any situation from electron microscopy to accelerator optics. The formalism based on the Dirac theory is further applied to the study of the spin-dynamics of a Dirac particle with anomalous magnetic moment being transported through a magnetic optical element.

This naturally leads to a unified treatment of both the orbital (the Lorentz and the Stern-Gerlach forces) and the spin (Thomas-Bargmann-Michel-Telegdi equation) motions. An alternate approach to the quantum theory of charged-particle beam optics based on the Wigner phase-space distribution function is also presented briefly. An alternate approach to the quantum theory of charged-particle beam optics based on the Wigner phase-space distribution function is also presented briefly.

4.11.5 Luisa Cappetta

Author: Luisa Cappetta (`luicap@vaxsa.csied.unisa.it`), the University of Salerno, Italy.

Institution: the University of Salerno, Italy..

Title: Wake Electromagnetic Field in Rings with Finite Conductivity and Thickness Walls.

Date: July 22, 1997.

Supervisor: Prof. Innocenzo Pinto (`pinto@vaxsa.csied.unisa.it`), the University of Salerno, Italy.

Abstract: The wake potential multipole expansion for short as well as coasting beams in pipes with imperfectly conducting walls of finite thickness are computed for infinite straight sections as well as circular machines. An exact solution is obtained in the k-domain, and then rephrased in the $s = z - \beta ct$ domain by exploiting the appropriate asymptotics appropriate to LHC-like or DAPHNE-like machines. Freespace as well as perfectly-conducting wall limits are readily recovered.

5: Forthcoming Beam Dynamics Events

5.1 Fifth International Workshop on Beam Dynamics & Optimization

Dmitri Ovsyannikov (`Dmitri.Ovsyannikov@pobox.spbu.ru`)
Institute of Computational Mathematics & Control Processes
St.Petersburg State University, Russia

June 29-July 3, 1998, at St.Petersburg, RUSSIA

The meeting will take place in the Peter hall of the main building of St.Petersburg State University (one of the masterpieces of Russian art) located at the historical center of the city.

The workshop is organized by St.Petersburg State University (Institute of Computational Mathematics & Control Processes and Faculty of Applied Mathematics & Control Processes), D.V.Efremov Institute of Electrophysical Apparatus (St.Petersburg), and Joint Institute of Nuclear Research (Dubna). This series of the BDO Workshops is supported by Russian Fund of Fundamental Researches.

Scope The objective of the Workshop is to bring together mathematicians, physicists and engineers to present and discuss recent developments in the area of mathematical control methods, modeling and optimization and theory and design of charged particle beams. This Workshop is the fifth event in a series which started in 1994.

Main Topics

- Nonlinear problems of beam dynamics: mathematical modeling, nonlinear aberrations, including space charge forces and the self-consistent distributions problem, long time beam evaluation, dynamic aperture and halo problems;
- Methods of control theory in the problems for the beam and plasma dynamics optimization;
- Mathematical modeling of the electro- and magnetic fields;
- Computing problems for beam physics, object-oriented modeling;
- Software for the beam dynamics and optimization.

Organizing Committee chairman - V.I. Zubov (Russia), co-chairman - D.A. Ovsyannikov (Russia), S.N. Andrianov, Yu.A. Budanov, N.S. Edamenko, A.B. Kurzhanskii, B.P. Murin, V.V. Petrenko, V.P. Stepanchuk, V.A. Teplyakov, M.F. Vorogushin, E.P. Zhidkov (Russia), A.N. Dovbnya (Ukraine), H. Mais (Germany), M. Berz, G. Gillespie, R. Jameson (USA), Y. Yamazaki (Japan). **Program Committee** chairman - D.A. Ovsyannikov (Russia), V.A. Belyakov, B.I. Bondarev, N.V. Egorov, O.I. Nikonov, Yu.A. Svistunov, I.P. Yudin, A.V. Zherebtsov (Russia), F. Meot (France), Yu. Tur (Ukraine), R. Ryne, A. Todd (USA), S. Kawata (Japan).

The Workshop languages are English and Russian (with mutual translation). The submitted Abstracts will be published to be available for participants during the Workshop. The contributed papers will be included in the Workshop Proceedings. A social program for participants and accompanying persons is planned.

All correspondence should be sent to: *BDO'98 SECRETERIAT* `bdo98@apcp.apmath.spb.su`
NII VM&PU, St.Petersburg State
University, Bibliotechnaja pl.2,
St.Petersburg, 198904, RUSSIA

Workshop Secretary is A.D.Ovsyannikov (`bdo98@apcp.apmath.spb.su`). Workshop Coordinator is N.S.Edamenko (`nick@apmath.spb.su`).

5.2 Mini-Workshop on IP Physics for Linear Colliders

Ming Xie `mingxie@lbl.gov` LBNL, telephone 510-486-5616

January 12-16,1998, Lawrence Berkeley National Laboratory, Berkeley, California. Hosted by Center for Beam Physics of Accelerator and Fusion Research Division of Lawrence Berkeley National Laboratory;
Organizer: Ming Xie, Local Advisory Committee: William Barletta (LBNL), Swapan Chattopadhyay (LBNL), Pisin Chen (SLAC), Kwang-Je Kim (LBNL), Hitoshi Murayama (LBNL,UCB), James Siegrist (LBNL,UCB).

There have been renewed interests in IP physics for linear colliders, driven by the need to re-optimize current designs to enhance performance and reduce cost, the need to reach higher energy, and the need to explore innovative IP schemes and drastically different parameter regimes that could potentially be reached with new acceleration methods. The Mini-Workshop is organized in response to these new developments in accelerator and high energy physics communities.

The Mini-Workshop will take place in the week immediately after the Workshop on Quantum Aspects of Beam Physics (`http://www.slac.stanford.edu/grp/ara/qabp/qabp.html`), while many experts attending the Quantum Workshop will be in the area. As seen from the program of the Quantum Workshop the subjects is quite diverse, the time available for IP physics related presentation and discussion will be limited. The purpose of having this mini-workshop focused is to be complemental to the Quantum Workshop. Extensive discussion and interactive activities will be emphasized, presentation time will be more flexible. Materials in the talks presented at the Quantum Workshop could be either bypassed or repeated with more details for discussions depending on audience response and program needs. It is hoped that this Mini-Workshop will provide a timely platform where the exciting development of the field especially during past ten years will be reviewed and reexamined in the light of the recent developments, and new topics of IP physics important for future linear colliders will be identified.

The topics for the Mini-Workshop include following categories: (1) Methodology for QED calculations of radiation by relativistic particle in strong external field, beamstrahlung, bremsstrahlung and coherent bremsstrahlung, incoherent and coherent pair creation, effect of inhomogenous external field. Review of Sokolov-Ternov, Baier-Katkov, equivalent photon method, etc. Landau-Pomeranchuk-Migdal effect. (2) Interaction of electron and photon with intense laser field for gamma colliders, nonlinear Compton scattering, Breit-Wheeler pair creation, polarization of electron and photon in strong laser field. (3) Robust particle physics experiments that can be done in a dirtier IP environment. QED and QCD background issues, jet production in gamma-gamma collisions. (4) Optimization of IP performance for robust particle physics experiments in legitimate collider parameter space. Constraints and limitations, options and tradeoffs for linear colliders based on rf acceleration for near term development and laser acceleration for long term development. (5) Other quantum treatment of linear collider related issues, such as radiation damping in presence of multiple scattering in crystal, radiation and pair creation in crystal, cooling of electron beams by Compton scattering, generation of polarized positron beam with electron beam and intense laser.

Being informal in style, the mini-workshop will not have such bells and whistle as companion program, gala banquet, proceedings in publication form or even a registration fee. Photo-copies of the presentations will be made available upon request to the participants. There will not be parallel working group sessions, and the number of participants will be limited. For more information and suggestions, please contact Ming Xie. The funding for the Mini-Workshop will be covered by a LDRD project of LBNL titled 'Interaction-Point Physics and Optimization Issues for Future

Linear Colliders'.

6: Announcements of the beam Dynamics Panel

6.1 16th ICFA Beam Dynamics Workshop

M. Cornacchia	`cornacchia@slac.stanford.edu`	SLAC
C. Pellegrini	`claudio@vesta.physics.ucla.edu`	UCLA

16th ICFA Beam Dynamics Workshop on
Nonlinear and Collective Phenomena in Beam Physics
Arcidosso, Italy
from the 1st to the 5th of September, 1998.

The Workshop will be sponsored by ICFA, the US Department of Energy, the National Institute for Nuclear Physics (INFN-Frascati, Italy), the National Institute for Alternative Energies (ENEA-Frascati, Italy), the National Laboratory for High Energy Physics, (KEK, Japan), the Lawrence Berkeley National Laboratory (LBNL, USA), the Stanford Linear Accelerator Center (SLAC, USA), the University of California at Los Angeles and the University of Rome ”La Sapienza”.

The meeting will center on three accelerator physics topics, discussed by Working Groups. After a talk on the general aspects of beam physics and nonlinearities, three Speakers will introduce the subjects on the first day and Group Leaders will provide a summary of the discussions on the last day. Following the formula of the previous workshops held in 1994 and 1996, the meeting will be organized in such a way as to leave as much time as possible to discussions and to minimize the number of formal plenary talks.

The Group on ”Single Particle Nonlinear Dynamics” will cover recent advances in nonlinear dynamics, including experimental results of turn-by-turn tracking, frequency analysis, mapping and halos. The Group Leader is D. Robin (LBNL) and the Speaker C. Biscari (INFN-Frascati).

The Group on ”Creation and Manipulation of High Phase Density Beams” will present and discuss advances in production, transport and monitoring of high brightness beams, including coherent radiation effects. The Group Leader is J. Rossbach (DESY) and the Speaker B. Carlsten (LANL).

The Group on ”Physics on, and Physics with, High Energy Density Beams” will concentrate its work on the novel problems and possibilities offered by high brightness particle and photon beams. These can be focussed to a small spot size to reach particle and power densities many orders of magnitude greater than those possible today, thus allowing studies in a parameter region not previously accessible. The Group Leader is T. Tajima (U. of Texas) and the topic will be introduced by A. Sessler (LBNL).

Arcidosso is a medieval town in Southern Tuscany, close to the city of Sienna. The meeting will take place in the evocative scenario of the 11-th century Aldobrandescan castle atop a hill dominating the nearby valley. The castle was restored in 1989, and preserves the atmosphere and raggedness of medieval times. Tours for participants and companions will be organized.

For information on the workshop, contact

Ms. Melinda Laraneta	`laraneta@physics.ucla.edu`	UCLA

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A home page for this workshop will be made soon. It will have a link from the home page of UCLA Particle Beam Physics Lab:

`http://pbpl.physics.ucla.edu/`

6.2 ICFA Beam Dynamics Mini-Workshop on Beam Loading

W. Chou	`CHOU@adcon.fnal.gov`	Leader of the High-Brightness Hadron Beams WG
Y. Mori	`moriy@kekvax.kek.jp`	KEK, chair
C. Ohmori	`chihiro@kekvax.kek.jp`	KEK, secretary

ICFA Beam Dynamics Mini-workshop on
”Beam Loading in High Intensity Hadron Synchrotrons”
KEK-Tanashi
from February 23-25, 1998

The purpose of the workshop is to discuss the basic problems of beam loading and to examine its cure and compensation in high intensity hadron synchrotron. Other topics such as barrier bucket and impedance control will be covered. The beam loading issues of the JHF 50-GeV ring, in which a magnetic-alloy loaded RF cavity is to be used, will be also examined and worked in a case study.

Scientific Topics

1. Basic Problems of Beam Loading
   - (a) Single-bunch Effect
   - (b) Multi-bunch Effect
   - (c) Transient Beam Loading
   - (d) Higher Harmonics Cavity
   - (e) Non-linear beam loading
2. Cure and Compensation (Feedback/Feedforward)
   - (a) System Design
   - (b) Hardwares (Pick-up, Filtering, Amplifier) , etc.
3. Other Topics
   - (a) Barrier Bucket, Impedance Control , etc.

More information can be found in the following WWW site:

`http://hatokyo1.tanashi.kek.jp/jhf/workshop.html`

6.3 Report of Tau-Charm Factory Working Group Meeting

Elcuno A. Perelstein `perel@nusun.jinr.dubna.su` Leader of the Tau-Charm Factory Working Group

The meeting of the Tau- Charm Working Group (TCF WG) of the ICFA Beam Dynamics Panel was held at Frascati, the 24th October, 1997 during the Advanced ICFA Beam Dynamics Workshop on Beam Dynamics Issues for e^+e^- Factories (20- 25.10.1997). Nine of working group members: P. Beloshitsky, Chuang Zhang, Dong Wang, S.Kamada, Ying Zhi Wu, L. Palumbo, E. Perelstein, J. Le Duff, A. Zholents, Ying Zhi Wu and Beam Dynamics Panel chairman K. Hirata attended the TCF WG meeting. The future TCF WG activity was discussed. TCF WG proposed that next ICFA Workshop on e^+e^- factories would be held at 1999 at Beijing to promote the studies of beam dynamics problems on the e^+e^- factories and especially on the TCF in China, Russia and other places.

At present three new factories is under construction and will be completed by 1999. There are two B factories in SLAC and KEK and a ϕ factory at Frascati. Now the commissioning of the ϕ factory successfully begins. All modern factories including the TCF have many common features in principle. That means the two separated ring optics and crossing angle problems, the design of the interaction region and beam- beam interaction problems, instabilities and feed back systems etc. So an experience obtained at B- factories and ϕ factory will be very useful for TCF designing. On the other hand, the problems of magnet lattice flexibility to provide the various operation modes of a factory, the monochromatization of polarized beams and other are the problems of the common interest. The previous Workshop on the TCF was held at 1996 where the physics, detector, and accelerator problems were under discussion. So it would be useful to provide an update review on Tau-Charm physics at TCF session. The members of the TCF WG appreciated the hospitality and the high level of the local organizing committee of the Frascati ICFA Workshop.

6.4 ICFA Beam Dynamics Newsletter

Editors in chief

Kohji Hirata (`hirata@kekvax.kek.jp`)
John M. Jowett (`John.Jowett@cern.ch`)
S.Y. Lee (`shylee@indiana.edu`)

6.4.1 Aim of the Newsletter

The ICFA Beam Dynamics Newsletter is intended as a channel for describing unsolved problems and highlighting important ongoing works, and not as substitute for journal articles and conference proceedings which usually describe completed work. It is published by the ICFA Beam Dynamics Panel, one of whose missions is to encourage international collaboration in beam dynamics.

6.4.2 Categories of the Articles

It is published every April, August and December. The deadlines are 15 March, 15 July and 15 November, respectively.

The categories of articles in the newsletter are the following:

1. Announcements from the panel
2. Reports of Beam Dynamics Activity of a group

3. Reports of Beam Dynamics related workshops and meetings

4. Announcements of future Beam Dynamics related international workshops and meetings.

   Those who want to use newsletter to announce their workshops etc can do so. Articles should typically fit within half a page and include descriptions of the subject, date, place and details of the contact person.

5. Review of Beam Dynamics Problems

   This is a place to put forward unsolved problems and not to be used as the achievement report. Clear and short highlights on the problem is encouraged.

6. Letters to the editor

   It is a forum open to everyone. Anybody can show his/her opinion on the beam dynamics and related activities, by sending it to one of the editors. The editors keep the right to reject a contribution.

7. New Doctoral Theses in Beam Dynamics

   Please send announcements to the editors including the following items (as a minimum):

   (a) Name, email address and affiliation of the author,

   (b) Name, email address and affiliation of the supervisor,

   (c) Name of the institution awarding the degree,

   (d) The title of the thesis or dissertation.

   (e) Date of award of degree. (For a while, we accept the thesis awarded within one year before the publication of the newsletter.)

   A *short* abstract of the thesis is also very desirable.

8. Editorial

All articles except for 6) and 7) are by invitation only. The editors request an article following a recommendation by panel members. **Those who wish to submit an article are encouraged to contact a nearby panel member**.

The manuscript should be sent to one of the editors as a LaTeX file or plain text. The former is encouraged and authors are asked to follow the instructions below.

Each article should have the title, author's name(s) and his/her/their e-mail address(es).

6.4.3 How to Prepare the Manuscript

Here, the *minimum* preparation is explained, which helps the editors a lot. The full instruction can be found in WWW at

`http://www-acc-theory.kek.jp/ICFA/instruction.html`

where you can find the template also.

Please follow the following:

- Do not put comments (%) when sending the manuscript through e-mail. Instead, you can use `\comm` as `\comm{your comments}`.
- Start with `\section{title of your article}`. **It is essential**.
- Then put your name, e-mail address and affiliation.
- It is *useless to include any visual formatting commands* (such as vertical or horizontal spacing, centering, tabs, etc.).
- Do not define new commands.
- Avoid TEXcommands that are not part of standard LATEX. These include the likes of `\def`, `\centerline`, `\align`, ...
- Please keep figures to a minimum. The preferred graphics format is Encapsulated Postscript (EPS) files.

6.4.3.1 Regular Correspondents

Since it is impossible for the editors and panel members to watch always what is going on all around the world, we have started to have *Regular Correspondents*. They are expected to find interesting activities and appropriate persons to report them and/or report them by themselves. We hope that we will have a ”compact and complete” list covering all over the world eventually. The present *Regular Correspondents* are as follows

Liu Lin (`liu@ns.lnls.br`)	LNLS	Brazil
S. Krishnagopal (`skrishna@cat.cat.ernet.in`)	CAT	India
Ian C. Hsu (`ichsu@ins.nthu.edu.tw`)	SRRC	Taiwan

We are calling for more volunteers as *Regular Correspondents*.

6.4.4 Distribution

The ICFA Beam Dynamics Newsletters are distributed through the following distributors:

W. Chou	chou@adcon.fnal.gov	North and South Americas
Helmut Mais	mais@mail.desy.de	Europe* and Africa
Susumu Kamada	kamada@kekvax.kek.jp	Asia** and Pacific

(*) including former Soviet Union.
(**) For mainland China, Chuang Zhang (`zhangc@bepc5.ihep.ac.cn`) takes care of the distribution with Ms. Su Ping, Secretariat of PASC, P.O.Box 918, Beijing 100039, China.

It can be distributed on a personal basis. Those who want to receive it regularly can ask the distributor to do so. In order to reduce the distribution cost, however, please use WWW as much as possible. (See below).

6.5 World-Wide Web

The home page of the ICFA Beam Dynamics Panel is at the address

`http://www-acc-theory.kek.jp/ICFA/icfa.html` (which happens to be in Japan). For reasons of access speed, there are mirror sites for Europe and the USA at

`http://wwwslap.cern.ch/icfa/`
`http://www.indiana.edu/~icfa/icfa.html`

All three sites are essentially identical and provide access to the Newsletters, Future Workshops, and other information useful to accelerator physicists. There are links to information of local interest for each area.

6.6 ICFA Beam Dynamics Panel Organization

The mission of ICFA Beam Dynamics Panel is *to encourage and promote international collaboration on beam dynamics studies for present and future accelerators*. For this purpose, we publish *ICFA Beam Dynamics Newsletters* three times a year, we sponsor *Advanced ICFA Beam Dynamics Workshops* and *ICFA Beam Dynamics Mini-Workshops*, and we organize *Working Groups* in the panel to promote several important issues.

Chairman K. Hirata

Chief Editors of ICFA Beam Dynamics Newsletter K. Hirata, J. M. Jowett, S. Y. Lee

Distributers of ICFA Beam Dynamics Newsletter W. Chou, H. Mais, S. Kamada

Leader and Subleader of Future Light Source Working Group K. J. Kim and J. L. Laclare

Leader and Subleader of Tau-Charm factory Working Group E. A. Perelstein and C. Zhang

Leader of High-Brightness Hadron Beams Working Group W. Chou

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