Summary of the Workshop

Presentations and Discussions

Session 1: Status of Projects in Design/Construction

BESSY II

The construction of the main building is well advanced, and is expected to be complete in Dec. '96. The installation of the 10 Hz 1.9 GeV booster is now in progress and commissioning will start in a few months, aiming for a full energy beam in April 1997. The storage ring main magnets are being measured and the main magnet power supplies are being tested and delivered. The DORIS r.f. cavities will be installed in the next few months. The technique of explosion bonding copper to stainless steel has successfully been used for the construction of the vacuum chamber radiation absorbers. It has been found that stringent quality control is very important to eliminate some defects that were observed. The first ID structures are being mechanically tested and an ID of 49 mm period length will be ready in the following weeks. First beam is being aimed for mid 1998 with user operation in January 1999. Six beamlines from insertion devices and eight from bending magnets should be available at an early stage of the project. The present plan is that BESSY I will run in parallel with BESSY II for about two years and then be shutdown in 2001.

ANKA

The "green light" for the ANKA project was given on March 12th 1996. The facility, (50 MeV microtron/500 MeV 10 Hz booster/2.5 GeV storage ring) will be housed in a large 60 m x 60 m building. The lattice is presently being defined along with the power supplies, radio frequency components, vacuum and injection. For the control system two possibilities are being examined, the ESRF system and a field bus concept using PC's. The lattice is a "double DBA" type, recently modified to be asymmetric with two long (6.8 m) and two short (3.8 m) straight sections. The circumference is 103.2 m and the emittance 88 nmrad with zero dispersion, or 45 nmrad with non-zero dispersion in the long straights, at the same working point. The dynamic aperture is sufficient in either case even without using harmonic sextupoles. The main magnets have been redesigned and the quadrupoles are the same as BESSY II. Four ELETTRA type cavities will be placed in the dispersive sections, one in each arc, which will be sufficient for a beam current of 200 mA. A new solution with two cavities fed by a 250 kW klystron is being considered. For 400 mA two more cavities are required. A simple design for the booster having four 90° bending magnets is being examined.

SLS

Changes to the lattice design have resulted in an increase of the circumference to 288 m. There are now 3 long straight sections of 12 m, 3 of 7 m and 6 short sections of length 4m, the latter with low b values for small gap and high field insertion devices. The original 16 m long straights have been reduced to 12 m on the advice of the Scientific Advisory Committee. The emittance is 2.8 nmrad, 1.9 nmrad with non-zero dispersion in the shorter straight sections. The energy acceptance has been increased to 6%. The required r.f. voltage of 4 MV is obtained with a two phase r.f. system: ELETTRA-type normal conducting cavities will provide 2.2 MV, augmented by a passive superconducting cavity. The possibility of including superconducting bends in the TBA lattice is still open, but there is also the option of superconducting wavelength shifters in the short straights.

The injection system is made up of a 100 MeV linac and a 2.4 GeV maximum energy booster synchrotron. The booster is a combined function machine housed in the storage ring tunnel with a low 5 nmrad emittance that would be beneficial for topping-up. A simple 20 mm steel vacuum chamber without reinforcement is proposed; work is in progress to reduce the cost of the vacuum pumps for the long, poor conductance chamber. A 2 MeV r.f. gun is already working delivering half of the required current. Conventional and laser driven cathode guns are also being examined.

A final version of the building design will be ready by mid December 1996, selected from four competitive proposals. The service gallery and control room will be housed inside the building. The floor is a 50 cm reinforced slab, with no expansion joints, based on the APS philosophy. To lower the costs steel pillars and a wooden roof will be used.

The present preparation phase is funded by the PSI running budget. The final Parliamentary decision is expected in June ’97, when it is hoped to start the ordering of components.

SOLEIL

Construction of SOLEIL is expected to commence in 1999 and begin operations in 2003. In 2001 the present machines at LURE will stop operation. Several major design options have recently been revised. The injector will now be exclusively an electron machine rather than positron; the shorter linac implies that the linac and booster can now be placed inside the storage ring. The ring energy has been increased from 2.15 GeV to 2.5 GeV so that the requirement for 10 keV photons can be met more easily with a 15 mm gap undulator (U3.4) rather than the previous 4 mm (U1.6). The change in energy requires an increase in the length of the dipole magnets, which are already 1.6 T. In addition, the lattice has been modified to recover an emittance of 3 nmrad. The 16-cell lattice will provide 4 long straight sections of 14 m (required for the FEL) and 12 of 7 m. The r.f. system will be based on mono-mode 353 MHz superconducting cavities, providing an accelerating voltage of 2.3 MV, giving an energy acceptance of 4%. The cavities will be developed by a collaboration between CERN, ESRF, SOLEIL and DIAMOND; a full power test of a cavity is planned for the end of ’98. Additional developments foresee the use of individual power supplies for the storage ring quadrupoles, thinner vacuum chamber, transverse orbit feedback, IR-FEL. The ESRF-DESY beamline control system will be used. The r.f. frequency of the booster has been changed from 100 MHz to 353 MHz; a decision has yet to be made on the repetition frequency, either 1 or 10 Hz.

SRS Upgrade

The SRS upgrade is seen as a "technology demonstrator" for the DIAMOND project, and involves the installation of two 9-pole 2T multipole wigglers providing up to 20-30 keV photons for 4 new experimental stations. The project has been approved and funding should start in Jan. 1997. The placement of the wigglers requires a complete relocation of the r.f. system. The novel vacuum chambers for the devices will be constructed from titanium (1.2 m flange to flange) with a beam stay clear of 15 mm and magnet gap of 19 mm.

DIAMOND

The present 3 GeV racetrack lattice has 2 long (20 m) and 14 short (5 m) straight sections with an emittance of 14 nmrad. Six families of harmonic sextupoles are required to give a dynamic aperture that exceeds the ±20 mm horizontal aperture, however this is reduced significantly at 3 % momentum deviation. Steerer magnets will be provided by additional coils in the sextupole magnets. Extensive studies show little reduction of dynamic aperture due to the insertion devices. A superconducting r.f. system (cf. SOLEIL) is being considered. Various options for replacing pairs of conventional dipole with 4.3 T superconducting dipoles have been studied. The design of the full energy booster synchrotron is based on a double FODO cell structure with sextupoles in alternate straights. Current work involves finalising the feasibility report, including a detailed costing, reviewing the super-long straights and considering other machine symmetries, as well as identifying possible funding sources and mechanisms.

LSB

The 2.5 GeV, 12-cell TBA lattice and its main components have now been fixed. The lattice provides low emittance (8 nmrad) and potential for future upgrades: an increase in energy to 3.0 GeV, inclusion of super-conducting bending magnets and low-beta sections. The momentum acceptance is 2.3%. A laboratory is being built for magnetic measurements and there are plans for the construction of a prototype bending magnet and insertion device. A first set of generic beamlines are being studied. A feasibility study should be produced by Sep./Oct. 1997.

Session 2: Status of Projects in Commissioning or Operation and Future Upgrade Plans

ESRF

The facility now includes 26 operational beamlines, which will increase to 39 by the end of Phase II (end ’98). The machine reliability is very good, with 95 % average up-time in ’96 and mean time between failures of 41 hours. Reliability has been increased significantly by the non-interruptable power supply, which avoided more than 220 electrical fluctuations. Only occasional direct hits by lightening now cause machine stoppage. Operation of a second klystron has also reduced downtime due to the r.f. system. Seven different filling modes are currently used. The lifetime increase in 2/3 filling compared to 1/3 filling clearly shows that the Touschek effect also plays a role with high energy machines. Machine developments in ’96 have included new lattice functions with low vertical beta in all straight sections, reduction of the coupling to 1 %, development of 8 mm internal/10 mm external copper-plated vacuum vessels, and the test of a Spring-8 in-vacuum undulator. The first new filters have also been installed on the beam lines to allow the use of three undulator sections with 200 mA stored current. The goals for 1997 are 5400 hours for user operation (with about 18% of the total time dedicated to start-up and machine studies), commissioning of a third r.f. plant and installation of the new low gap ID chambers. Studies will also be made for a further reduction in the emittance (3 nmrad) and coupling (0.3 %).

MAX II

The commissioning phase for MAX II has now ended and the operational phase is beginning. Both the design energy and current have been reached. MAX I is used as the injector providing 30 mA/shot, once per minute, allowing a re-filling time of 10-20 minutes. The capture efficiency between the two machines is about 40 %. MAX II has non-zero dispersion in the straights. The sextupole fields for chromaticity compensation are generated in the quadrupoles, with backleg coils for adjustment. No major problems have been observed due to the integrated sextupole fields; two different optics have been tried, although not greatly different in sextupole strength. SIP’s in the bending magnet chambers are used for pumping and titanium sublimation pumps are used once per week. The lifetime is lower than foreseen (0.7 Ah, instead of 2 Ah) and is probably due to the lower coupling than expected (1 rather than 10%). The energy acceptance is 1.5%. There is little demand for short bunch lengths and a greater demand for low emittance and so rather than acting on the coupling to increase the lifetime a Landau cavity, working at the third harmonic 1.5 GHz, will be installed to increase the bunch length. At the same time it will combat multi-bunch instabilities by providing synchrotron tune spread. No bunch length measurements have yet been performed. The first phase of beamline construction foresees the installation of four beamlines for insertion devices and two from bending magnets.

DORIS III

The last major rebuilding of the facility has been to remove the vertical bending magnets in order to eliminate the vertical dispersion, as well as to save money on electrical power. A new ID vacuum chamber has been installed with 11 mm internal and 15 mm external dimension, consisting of copper halves soldered together with distributed NEG pumping. Nine photon beam position control loops are in operation using information from photon beam monitors. Closed orbit movements have been traced to the asymmetric heating of the dipole chambers at the ID outlet, causing movement of the adjacent quadrupole chamber, and also of the quadrupoles themselves. Six new chambers will therefore be installed in mid ’97 with additional cooling on the inner side of the chamber; at the same time the fixing of the quadrupole vessels to the magnets will be removed. Overheating of the vertical multibunch feedback limits the current that can be obtained in the 5-bunch mode; to solve the problem a new design with water cooled ferrite will be installed during the next summer shutdown.

DELTA

First stored beam at 1 GeV was achieved in DELTA on the 16th August, followed by accumulation of 10 mA (limited by vacuum effects) in October. Radiation from the FELICITA 1 undulator has been observed and also transported out of the shielding wall. The ring is presently shutdown for bake-out and NEG activation. The linac is operating at 70 MeV due to an r.f. power limitation. The booster has recently been improved to increase the rep. rate (10 cycles/minute) and reduce beam losses. Stray fields from the booster which affect the storage ring have been noted. The plans for ’97 are to commission the 4-bunch FEL mode as well as the 1.5 GeV SR user mode, to install the optical cavity and obtain lasing.

Kurchatov Synchrotron Radiation Source

The six-fold symmetric storage ring, SIBERIA II, achieved full energy (2.5 GeV) and 10 mA in July ’96. By the end of the year 100 mA should be achieved, as well as the first experiments performed on the first 3 VUV beamlines. The chamber is made of aluminium with some parts in stainless steel. An 180 MHz r.f. system has been adopted. SIBERIA I is used as injector (450 MeV) with a cycling time of 30 seconds. A large number of beamlines are under construction. A collaboration for LIGA technology is in progress with the university of Mainz. In 1997 it is hoped to commence regular X-ray experiments with 300 mA beam current.

ELETTRA

ELETTRA is currently operating for a total of about 6100 h/yr. with 5000 h for users, and with an average up-time of about 92 %. The major source of down-time is due to storms, predominantly in the summer months. Injection is performed once per day at 1 GeV, followed by ramping to 2 GeV, with an initial current of 250 mA. The total time for a re-injection is around 20 minutes. There are no requests at present to operate in single bunch mode. Five IDs are operational as well as one bending magnet beamline. Higher order modes in the r.f. cavities are cured by a combination of cavity temperature adjustment and HOM frequency shifters. Some residual longitudinal excitation is accepted in order to increase the beam lifetime. Developments in progress include substitution of BPM gaskets to permit higher beam currents, installation of adjustable HOM frequency shifters in all 4 cavities, development of a transverse coupled bunch feedback system and a global orbit feedback system, and increased automation. An electromagnetic elliptical wiggler has been designed and will be installed in 1997. Lower gap ID vessels are also under study.

Session 3: Operational Aspects

Various operational aspects were discussed concentrating on methods for increasing the efficiency through increased levels of automation and better fault recovery, as well as aspects that are of particular interest to users, such as ID gap control etc.

Automation

New sources now have a much wider range of choices for the development of control systems compared to the past, given the increasing number of commercial systems and collaborative projects, e.g. the EPICS system which was chosen by BESSY II because of the large amount of support available. More recently, ESRF/DESY are proposing a standard system that can be applied to both beamlines and machine, and which can be made available to other laboratories. It has been selected by the SOLEIL project and is under consideration also by the SLS, which is also considering a industrial-based system. Cheap multi-node controllers are also available, i.e., LONWORKS, which although too small for the main control system should be a feasible and cheap solution for systems such as vacuum control. The SRS has developed a new PC-based control system.

ELETTRA is developing a 1bm ("one button machine") program, which allows the controlled execution of modules, including existing modules, to perform routine operational sequences. Such an approach is of particular benefit for a machine with many different operating modes. Both the ESRF and ELETTRA have closed automatic closed orbit correction performed in the background every few minutes. An automatic program triggered by a beam loss to record beam parameters has proved useful in fault diagnosis at the ESRF.

ID Control by Users

Pressure from users to have control of ID gaps is generally growing. User control is now partially allowed at the ESRF over limited gap ranges, however changes are still supervised by the control room to prevent mis-use. The largest closed orbit effect is given by helical devices, however correction coils are used to reduce the changes to less than 10 % of the beam size. Changes to the coupling have also been observed due to some helical devices. Low energy machines are more sensitive to gap changes and ELETTRA is planning to allow a limited user control in the near future.

User Requirements

An important topic at the ESRF is the provision of different filling modes. Apart from single bunch and 1/3rd or 2/3rd filling, several "hybrid" modes have been developed. It was pointed out that there is interest for certain types of experiment also for a completely uniform fill, which may be an additional requirement for new light sources to consider. It is planned to try this at the ESRF using a Qs-splitting cavity to damp longitudinal coupled bunch modes. Such a requirement led to a discussion of ion trapping effects. It has been noted in the past that such effects have been observed at SRRC and ELETTRA, whereas they were absent from both the ALS and ESRF. In recent experiments at ELETTRA the original observation of ion trapping (1994) was no longer clearly seen, and it is assumed that the gas pressure during the commissioning phase lead to enhanced trapping effects.

It was pointed out that some beamlines need a stability better than 10 % of the beam size: this is required for example on the ESRF helical undulator which switches helicity about every 30 minutes.

A new type of non-destructive gas ionization photon detector has been developed by the KSRS group which is capable of giving information about both beam position and cross-section, as well as absolute intensity. First results of tests made at DCI were presented.

Fault Recovery

The high up-time of the current facilities generally indicates a satisfactory situation with regard to preventative maintenance, fault analysis and recovery. Comments were made on the usefulness of having on-line diagnostic tools to allow efficient recovery of faults. Internet products now exist for such purposes, for example at the APS. Control systems should be flexible enough to allow the easy build up of monitoring programs which are an essential feature of present day facilities. It was pointed out that the availability of spares is also important, particularly in view of components becoming obsolete.

Beam Loss Monitoring

At the ESRF it has been discovered that beam loss is mainly from the Touschek effect acting in the vertical plane, arising from the large vertical chromaticity which generates a large tune variation with momentum leading to resonant loss. As a result, narrow gap IDs cause increased bremsstrahlung in the beamline, activation of the ID vessels and radiation damage of the IDs. Possible solutions are a small vertical beta function at the IDs, removing the need for a large vertical chromaticity by means of higher conductivity vessels or use of feedback, and full protection of losses by use of two defining scrapers. At ELETTRA the distribution of losses during a beam dump, performed by momentarily removing r.f. power, is found to be non-uniform with preferential loss symmetrically placed about one point in the ring.

Session 4: Orbit Stability

Orbit stability is of paramount concern for high brightness synchrotron radiation sources. Methods of overcoming both slow and fast variations were discussed. Several comments were made on the general topic of how best to implement orbit feedback systems. At present there is insufficient evidence whether photon BPMs can be made reliable enough, including the effects of ID gap changes, and so the use of electron BPMs has also to be considered. The question of whether local or global feedback is better, given that the electron BPMs are moving themselves, was discussed. Various opinions were expressed, such as that on the one hand global correction cannot perfectly correct the orbit and so leaves some residual errors, but that local correction is more sensitive to individual BPM movements and also that there could be a build up of errors if there are many loops active.

Slow Orbit Variations

Slow closed orbit movements due to changing synchrotron radiation load and cooling system fluctuations were reported at ELETTRA, MAX II and SRS. At ELETTRA, BPM and quadrupole movements during ramping were eliminated by means of additional cooling, while stress on the BPMs required development of a new gasket with an inner ring of copper and outer ring of stainless steel. Further orbit variations are also observed at ELETTRA after a ramp which can be correlated with water temperature variations, and which are overcome with an automatic slow local bump correction. Occasionally twenty-four hour orbit variations are also observed, the source of which is still unknown. At MAX II during the ramp the power dissipated in the quadrupole coils varies by a factor of ten and an associated periodic closed orbit variation is observed due to expansion of the magnet yokes. At the SRS, 100 μm horizontal movements are overcome with a global technique, while vertical movements are offset with local feedback; some difficulty is experienced however with the build up of the number of correction loops. The general conclusion is that full energy injection is clearly an advantage for orbit stability. To overcome effects due to magnet temperature variations, the interesting suggestion was made of maintaining a constant mean temperature, rather than stabilising the water inlet temperature.

Fast Orbit Fluctuations

At the ESRF the typical orbit fluctuations are 8 μm and 2.5 μm rms in the horizontal and vertical planes respectively, with a main component at the girder eigenfrequency of 7 Hz. The source is unknown, but not thought to be power supply ripple or induced by the cooling water. Provided data taking is slow, the orbit fluctuations give rise to a negligible change in effective source size, and so fast orbit correction may not be necessary. Some users however take data at a faster rate, in which case the sensitivity is greater and the usual 0.1 s criterion applies. Occasional beam vibrations can also be a problem, for example during closure of a beam shutter the closed orbit was seen to ring with the characteristic frequency of the magnet girders. Both local and global fast feedback systems are being developed, as well as APS-type girder damping.

At the SRS there is generally no need to worry about fast fluctuations because of the large beam sizes, however one user needs beam stabilisation at high frequencies (60-120 Hz) because of the way in which data is taken. Fast fluctuations are observed at ELETTRA in the 20-50 Hz range. A feedback development program is in progress using DSP's in conjunction with powerful mathematical software packages. The system uses photon BPMs with the option of switching to electron BPMs.

Session 5: Coupled Bunch Instabilities

Various techniques for overcoming coupled bunch instabilities were discussed including higher order mode (HOM) shifting, HOM free cavities and feedback systems as well as Landau cavities for increased tune spread either within the bunch or between bunches.

Mode Shifting and Mode Free Cavities

Coupled bunch instabilities are successfully cured at ELETTRA by means of mode shifting, using a combination of temperature control and HOM frequency shifters. The first direct evidence for a HOM driven instability has been seen at the SRS; the effect on the ID spectra as a function of HOM excitation was presented, as well as the cure of the instability through a combined change of cavity temperature and tuner position. To avoid the problems due to HOMs, SOLEIL is studying the use of superconducting cavities with HOM dampers.

Feedback Systems and Other Techniques

New possibilities for multibunch feedback systems have recently been opened up by the use of digital signal processing (DSP) systems. ELETTRA is developing a transverse feedback system in collaboration with DAfNE and PEP and first system tests are planned in Dec. '97.

MAX II will install a Landau cavity for the simultaneous increase in Touschek lifetime and to combat multibunch instabilities via the increased longitudinal tune spread within the bunch. The cavity will be passive because of the difficulty in finding klystrons at the frequency of 1.5 GHz. The resulting beam current range could however be quite small, because of the need to overcome the Robinson instability. BESSY I also has a double r.f system for bunch length control.

Session 6: Touschek Lifetime Limitations in High Brightness Machines

There is now adequate evidence that low natural emittance and low coupling limits the lifetime even in high energy rings due to Touschek scattering. For new rings the main challenge is to increase the Touschek lifetime by increasing the momentum acceptance, rather than compromise the beam brightness or bunch length. Problems related to the lattice design as well as r.f. systems for obtaining the large acceptance were therefore addressed. Various methods of manipulating the bunch density were also discussed as a means of increasing lifetime in existing high brightness machines.

Large Momentum Acceptance Lattices

The general difficulties of optimizing low emittance lattices with large momentum acceptance, particularly with low periodicity racetrack configurations were mentioned. For the SLS, a techniques which involves cancelling all resonance driving terms up to 3rd order was described.

It was pointed out that non-zero chromaticity has a large effect on the dynamic aperture e.g. in SOLEIL reducing from ± 4 %

(x=0) to ± 1.5 % (x=+1). At the ESRF a practical upper limit is found to the lifetime with an acceptance of about ± 2.5 %, due to the large tune spread induced by the large positive vertical chromaticity. A careful selection of working point and/or resonance compensation would therefore be required to enlarge the effective momentum acceptance in this case. It was pointed out however that high positive chromaticity is not used in all machines.

The need for large horizontal vacuum chamber apertures was also pointed out, to provide the betatron acceptance for particles that are Touschek scattered in dispersive regions. The SLS ± 32 mm chamber dimension limits the effective energy acceptance for Touschek scattered particles to between 8 % (h=0) and 4 % (h=hmax). The net result is a lifetime that limits with a voltage of 4 MV, equivalent to a ± 6 % energy acceptance. The need to position the septum strip sufficiently far out so as not to limit the dynamic aperture was also mentioned.

R.F. Systems for Large Momentum Acceptance

The r.f solution for the SLS is to adopt normal conducting ELETTRA-type cavities utilising temperature tuning of the higher order modes since this is a well-proven technique, compatible with the SLS time schedule. In the case of "unlucky" distributions of modes HOM frequency shifters can be utilised. If it proves necessary to increase the voltage in order to increase the Touschek lifetime, the plan is to install a single passive HOM-free super-conducting cavity. Detuned far from resonance such a cavity can provide an extra 2 MV. The possibility of using a higher frequency cavity is an option that may be considered.

Bunch Density Manipulations

At the ESRF an increase to 2/3 filling from the usual 1/3 improves the lifetime from 29 h to 44 h at 200 mA. A re-adjustment of the cavity temperatures is required because of higher order modes being excited. Other possibilities for increasing the lifetime that have been studied are the installation of a higher harmonic cavity and increasing the vertical coupling. In ELETTRA the lifetime can be made to vary between 7 h and 37 h at 250 mA depending on the coupling, vertical dispersion and excitation of longitudinal coupled bunch instabilities. Insertion device spectra taken under various conditions show that allowing a slight longitudinal excitation is a better way of increasing the lifetime compared to operating on the coupling resonance, a factor of two in lifetime being obtained for only a small reduction in peak radiation intensity. Another technique employed at BESSY I is to introduce noise via striplines to increase the vertical beam size by a factor two.

At the ESRF, measurements of coupling using a pair of X-ray pinhole cameras cast some doubt on the validity on the widely used single resonance formula to calculate the coupling based on the minimum tune separation. A large discrepancy is also observed in the case of the excitation of a single skew-quadrupole. The same system also shows that there are significant changes in coupling due to helical undulator gap changes.

Session 7: Insertion Devices

New Device Developments

ELETTRA is developing an electromagnetic elliptical wiggler in collaboration with BESSY and MAX-lab, capable of switching the radiation helicity at up to 100 Hz. The novel configuration is a double electromagnet with an open-sided structure. Further elliptical undulators and also a mini-gap in-vacuum undulator are being considered in conjunction with new beamline proposals that are presently being evaluated. The ESRF are working on two new prototypes, a 20 Hz pulsed helical device and a fast pulsed undulator which will provide radiation only from a single bunch when the machine is operated in "hybrid" mode. The ESRF also reported on recent tests of an in-vacuum undulator built by SPRING-8. The device was operated down to 5 mm gap, but was limited by problems caused by heating of the steel sheet covering the magnets.

Effect of Small ID Gaps

The "first-order" effect of reducing the insertion device gap, and hence the beam-stay-clear, is a reduction in lifetime due to the elastic gas scattering term. In this respect a low vertical beta function is clearly an advantage; at the ESRF for example, the new low vertical beta means that a minimum beam stay clear of 5 mm can now be accepted instead of 7 mm for the same 20% reduction in beam lifetime. For smaller gaps, instabilities and r.f. heating become important and so the resistivity of the chamber becomes an issue. At the SRS a new wiggler chamber with grooves for the poles is made from Titanium. The cost of the material is comparable to stainless steel, it is easily welded and maintains its shape. At the ESRF the resistive wall impedance has increased steadily due to the installation of ID vessels; further increase will be avoided however by the use of stainless steel vessels with a copper plating. At ELETTRA no resistive wall effects have so far been seen, a possible explanation being that the natural tune spread is sufficient to Landau damp the instability. The design and use of small gap devices must also take into account shims and tolerances which become a significant fraction of the gap.

Effect of Helical Devices on Beam Dynamics

As a general topic, the effects of elliptical devices on non-linear beam dynamics seems not to have received a lot of attention. Studies performed by ELETTRA and BESSY on the elliptical wiggler shows significant non-linear effects, and work is in progress to find a pole configuration to increase the dynamic aperture. To aid in the interpretation of dynamic aperture calculations in general, it was felt that more comparisons between prediction and measurement would be useful.

Optimum Lattice Functions

Various approaches to the definition of optimum beta functions were discussed. For brightness optimization for example, it was pointed out if there is a large mismatch between the photon and electron beam emittance then the resulting effective emittance is less sensitive to the beta value. It was also pointed out that a proper analysis would need to take into account the energy spread. The benefits of a large beta and positive alpha in the ID straights in order to produce a small beam size at the sample was illustrated for the case of the ESRF. Such a solution cannot be applied to all straights however since some beamlines already include horizontal focusing. There are implications also for the number of independent quadrupoles in the insertion straight. For SOLEIL the beam sizes and divergences at 25 m from the source were calculated for various photon energies, undulator lengths and couplings as a function of the beta function. It was concluded that a beta function in excess of 10 m is optimum, the dependence being more pronounced in the horizontal plane.

Radiation Damage

No examples of radiation damage of insertion devices during normal operation were reported. As a precaution, all devices are opened at injection in ELETTRA. At the ESRF, only the IDs in the first two high beta straights after injection were opened.

Session 8: Additional Topics

Vacuum System Performance and Specifications

A good vacuum system is an essential requirement of any SR facility in order to guarantee adequate beam lifetime, however the cost is also an important factor. Three possible ways for reducing vacuum system costs were discussed: no pre-baking, no in-situ bakeout and reducing the number of pumps. Recent experiments now confirm previous observations that there is no difference in desorption yield for pre-baked and not pre-baked stainless steel. In-situ bakeout reduces pressure rapidly and gives a "clean" vacuum, but at the expense of thermal stress, possible leaks, and non-negligible cost and effort. Experience at ELETTRA suggests that in-situ bakeout is not necessary, and preliminary conclusions from experiments at DCI support this. The elimination of bake-out would also ease the construction of the vacuum chamber, for example bellow sections could be reduced in number or shortened. However, long ID chambers and r.f systems may still have to be baked-out to guarantee performance. Also, it was pointed out that the chamber geometry can strongly influence the desorption rate because of restrictions to the photo-electron paths. Finally, experience at ELETTRA and DESY suggests that many fewer pumps are needed to maintain UHV conditions than are often assumed during the design stage.

Storage Ring FEL s

Six storage ring FELs have so far been operated, however the lowest wavelength reached is still 240 nm obtained at VEPP3 in 1988. Progress in reducing the wavelength has not therefore been very rapid, one of the major problems being tackled is damage to the cavity mirrors. Nevertheless, it is generally believed that storage ring FELs will make advances in the near future, particularly with the advent of new dedicated rings such as DELTA and Duke University - the first lasing of the latter at 350 nm was announced at the Workshop. It was speculated that the 150-200 nm region should soon be a accessible using normal incidence optics, 30 nm using ring cavities, and eventually possibly wavelengths as low as 4 nm using harmonics etc.. In the present context the main issues are the compatibility of the ring design and FEL operation with the needs of a high brightness synchrotron radiation facility. For this reason the SASE mode, requiring generally a very long undulator, possibly in a pulsed by-pass, is not very attractive compared to an oscillator. SuperACO can support FEL and SR operation at the same time at 800 MeV, however higher energy rings involve some compromise, for example SOLEIL will operate at 1.5 GeV for the FEL, however the ring is optimized at 2.5 GeV for SR users. An alternative possibility in the case of the SLS project is the use of the extracted low emittance beam from the booster.

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