EUROPEAN SYNCHROTRON RADIATION STORAGE RINGS[1]

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The list of European synchrotron radiation sources is updated. It shows several new facilities coming into operation, or very close to completion. Their characteristics show the present trends of the community.

New projects are announced. The capabilities are extended in the countries already equipped, and new countries are willing to build synchrotron radiation sources. All this confirms the vitality of the discipline.

I. OVERVIEW OF THE EUROPEAN SITUATION

The community of synchrotron radiation users is developping at a fast and regular pace. New techniques appear and new sources are constantly needed. Europe participates in this trend, as I shall show here by a survey of the West European sources.

In the exhaustive list [1] of sources throughout the world which has been compiled by V. Suller for the 1992 EPAC there were 70 rings planned, operating or in construction. Among them, 20 were European : 9 in operation, 6 under construction, and 5 projects. Since then, the operation column lost ADONE now closed, and gained DELTA, ELETTRA, ESRF and MAX II, making a total of 12 rings in operation. BESSY II went from the planned to the construction phase, and 5 new projects are presently announced. The situation is now 12 rings operating, 3 under construction, and 9 planned.

There is no general body in Europe comparable to the DOE or NSF, and no uniform policy governing the development of Science or scientific tools. Decisions concerning programs are made separately, and independently by the governments of European countries, and therefore the history of synchrotron radiation sources in Europe depends much on the local traditions of machine builders and machine users. A remarkable exception to this situation is the ESRF, an international facility on the model of CERN and the ILL, initiated by the European Science Foundation, and whose scientific goals were assigned after a wide study of european needs and capabilities made by over 140 scientists and engineers.

Moreover, some degree of synchronization is provided by informal links between actors in the field, in particular through conventions and meetings. A biannual European Particle Accelerator Conference (EPAC) held under the auspices of the European Physical Society provides a forum on the general field of accelerators. As far as synchrotron radiation storage rings are concerned, two annual informal workshops have already been held at the ESRF, and this tradition is likely to be continued in the future in other places.

Despite the independance of the actors, there appears to exist a certain logic in the distribution of storage rings between the different generations as defined by H. Winick [2] and between the different photon energy ranges. To simplify, I shall use a half logical, half chronological classification of the sources which seems more convenient for a small sample, and distinguish between two fundamental energy domains : the low energies, up to a few keV, referred to as "VUV", and the higher energies, above 1 keV, referred to as "X". Detailed references on the different rings can be found in [1] and I shall just add the more recent ones.

To begin with, there is no dedicated lithography ring. The experimental ring COSY has been abandoned, and HELIOS, built in Great Britain for IBM is now in the US.

II. PARTLY DEDICATED SOURCES

The first group counts four partly dedicated sources listed in Table 1. ELSA [3] in Bonn is an electron pulse stretcher. Six dipole ports are available, and approximately a quarter of the time is devoted to synchrotron light users. ASTRID [4] in Aarhus is an interesting machine, storing ions and electrons six months per year each. Three beamlines are operating, and a VUV undulator is under construction. There are plans for a dedicated ring. Then come two dutch sources, not yet operating. In Amsterdam, AmPS [5] has been functionning as a pulse stretcher since 1992, and EUTERPE, in Eindhoven aims at synchrotron radiation and beam physics studies. Both rings have projects for a low emittance mode.

This class of synchrotron radiation sources illustrates the importance of local situations. These active centers overcome funding difficulties by associating different communities around a single machine. The drawback is the time it takes to reach the objectives, and that is why two of theses rings are still in the "planned" state as far as synchrotron light itself is concerned.

Table 1 : Multipurpose sources.

Name	Country	First Beam	Emittance	Energy
ELSA	D	1988	900 nm	3.5 GeV
ASTRID	DK	1991	160 nm	580 MeV
AmPS	NL	1992	100 nm (5 nm)	900 MeV
EUTERPE	NL	> 1995	160 nm (8 nm)	400 MeV

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Table 2 : Established sources.

Name	Country	Generation	First Beam	Emittance	Energy	Dipole ports	Insertions	Particles
DORIS III	D	1	1973	430 nm	4.5 GeV	12	10	e^+
DCI	F	1	1976	1 300 nm	1.85 GeV	3	1	e^+
SRS	UK	2	1980	110 nm	2.0 GeV	9	2	e^-
BESSY I	D	2	1982	55 nm	800 MeV	24	3	e^-
MAX I	S	2	1985	50 nm	550 MeV	8	2	e^-
Super-ACO	F	3	1987	37 nm	800 MeV	8	4	e^+

III. SOURCES OF THE 80'S

The facilities listed in Table 2 delivered their first dedicated photon beams in the 80's. They span the three generations, and belong to two categories : three X-ray sources, and three VUV. The by-pass added to the 4.5 GeV collider DORIS [6] in Hamburg makes it an attractive source serving 10 insertion devices and 12 dipole ports. The stored particles are positrons. This particular feature is shared by the other former collider, DCI in Orsay, where it contributes to a long lifetime of over 100 h. The light coming from the three dipole ports from serve 16 experiments, and 6 others are fed from a 5 pole superconducting wiggler delivering a 50 mrad wide fan. The third X-ray ring, SRS [7] in Daresbury, is the first second generation source of this set, and its emittance is the smallest. It has 9 dipole ports, and 3 insertions in operation.

The VUV machines are more recent. The trend towards smaller emittances initiated at SRS is continued. Due to the lower energy, the Touschek effect reduces the lifetimes. BESSY, in Berlin with its 24 dipole ports and 3 insertions is very densely used, while MAX I, in Lund still has some possibilities for extension. Super-ACO, in Orsay shares the linac injector with DCI and also stores positrons. It works half time in the temporal mode, usually with two 100 mA bunches, and part time with the Free Electron Laser acting as a user UV source.

Super-ACO was the first third generation machine, that is designed from the start with a low emittance, and to accomodate several insertion devices. It remained the only one until the ESRF went on line.

This class of rings is actually the most complete. They exhibit the widest variety in energies, emittances, and sign of stored particles, as can be seen in the Table 2. But this table does not show the particular histories of these rings. Almost all of them have been modified and improved. Not only new beamlines have been added, have been reduced. They served as test benches for new techniques for the sources, and for the beamlines as well.

IV. SOURCES OF THE 90'S

The recent rings are listed in Table 3. They exhibit a small emittance, lower than 10 nm.rad, and rely much on insertions. ESRF [8] in Grenoble is the only facility dedicated to hard X-rays in the world. It will soon be joined in this energy range by the APS and SPring8. The italian VUV source ELETTRA [9] in Trieste is comparable to the ALS. Both ESRF and ELETTRA are currently delivering photons to their users. Two more are in the commissioning phase, DELTA in Dortmund, and MAX II [10] in Lund. BESSY II [11] in Berlin will start in 1997.

Apart from the ESRF, the rings of this set are oriented towards VUV and soft X-rays, but with a higher beam energy than the older ones to overcome the Touschek lifetime limitation, and to take advantage of the lower field in the insertions. The experience of the preceding machines has been used to make a big step forward towards ever smaller emittances.

I want to mention here an IR source of a completely different design. CLIO [12] in Orsay, is a linac based FEL, working for external users since 1992. Last year after having delivered 1 500 h of useful beam between 1.8 and 17.5 µm, the machine was upgraded, to reach 50 µm. It is now operating since february.

Table 3 : Present generation.

Name	Country	First Beam	Emittance	Energy
ESRF	F	1992	8 nm	6 GeV
ELETTRA	I	1993	4 nm	1.5 GeV
DELTA	D	1995	10 nm	1.5 GeV
MAX II	S	1995	9 nm	1.5 GeV
BESSY II	D	1997	6 nm	1.7 GeV

V. A NEW LIFE FOR ACO

Before beginning the survey of future machines, I would like to pay a tribute to the oldest collider. ACO, in Orsay which stored its first beam in october 1965, served as a collider solely first, then part time photon source since 1968, and from July 1976 dedicated source, until its last shut down in April 1988. Since then, the hall has been cleaned up, and it is managed by a foundation "Sciences ACO", devoted to cultural action, and to be a link between research, public, industries and the educational world.

VI. PLANS FOR THE FUTURE

A number of new projects are being studied in different countries. They are listed in Table 4. ANKA [13] is the only one definitely oriented towards industrial uses such as analysis and micromechanics. DIAMOND [14] in the UK and SOLEIL [15] in France should replace existing rings. The Danes consider a fully dedicated ring to join ASTRID, and the British are considering a VUV ring, SINBAD [14]. Spain with LLSB and Switzerland with SLS [16] are two new countries joining the club. Two more opportunities are being considered : using the radiation of PETRA and DAΦNE as used to be done with the first generation.

At this time, these projects are not funded. There is therefore no defined time schedule, and the characteristics are still subject to change. I shall therefore be cautious in driving conclusions as to possible trends. It seems that the VUV rings (with the exception of SINBAD) aim at a higher beam energy, in order to improve the lifetime, and perhaps also to cover a wider energy range. Also, the double bend based lattice appears often. Compared to the present series of rings, the emittance values are much more dispersed. To understand this, it must be borne in mind that the conditions vary much in the different countries. Germany has a large variety of sources, and the new project ANKA can be designed for a very specific use, namely industrial applications. Denmark, the United Kingdom and France have already working sources, with well trained communities of users who follow their own traditions, and need extensive access to synchrotron radiation. The situation of Switzerland and Spain who are creating a new domain of research is obviously different.

Table 4 : Projects.

Name	Country	Emittance	Energy	Lattice
ANKA	D	45 nm	2.5 GeV	DDBA
ASTRID II	DK	63 nm	1.4 GeV	DBA
DIAMOND	UK	15 nm	3.0 GeV	DBA
LLSB	E	10 nm	2.5 GeV	TBA
SINBAD	UK	< 10 nm	700 MeV	DBA
SLS	CH	3.2 nm	2.1 GeV	7BA
SOLEIL	F	4 nm	2.15 GeV	DB

VII. CONCLUSION

The early successes of the young rings ESRF, ELETTRA, and the ALS show that many of the challenges described by A. Jackson [18] at the Tsukuba Conference have been properly mastered. A strong confidence in the calculation codes to predict the emittances, the dynamic acceptance and the instability thresholds has been gained because no unknown effects have shown up. The techniques of heat absorption are well mastered.

On the other hand, realization of small vacuum chamber impedances remains an important issue. Also, some progress is still needed to stabilize the beams against instabilities and ground motion as well. But progress is going on, and new techniques for feedback and contact fingers are being tested.

All this is very encouraging for the success of the new projects. The main problem which remains is beyond our technical knowledge : funding.

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