STATUS AND PLANNED DEVELOPMENT OF THE SINGAPORE SYNCHROTRON LIGHT SOURCE

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Abstract

After a construction period of 4 years the Singapore Synchrotron Light Source (SSLS) at the National University of Singapore went into pilot user operation in October 2001. Beam lines active or coming up within 2002 include lithography for micro/nanofabrication, phase contrast imaging, surface science, infrared spectro/microscopy, and X-ray diffraction and absorption. Further beam lines are under discussion with user groups. The Microtron Undulator Radiation Facility (MURF) is under development to provide highly brilliant VUV radiation and to prepare for subsequent development of an X-ray FEL. In the spirit of a national facility, SSLS is catering for the needs of universities, research institutes, and industry in Singapore and the region.

1 INTRODUCTION

From its original conception the Singapore Synchrotron Light Source has evolved into a general purpose synchrotron radiation facility serving research organisations and industry with synchrotron radiation applications from basic research to advanced manufacturing and covering the scope of a national facility. Within about four years from approval the facility was set up and went into operation involving users. In the following, the status achieved and the development planned will be described.

2 STATUS

Fig. 1 shows the building of SSLS situated on the campus of the National University of Singapore.

2.1 Machine

At SSLS, synchrotron radiation is mainly produced from the compact superconducting storage ring Helios 2. Fig. 2 shows Helios 2 in the premises of Oxford Instruments while fig. 3 shows a picture taken inside the radiation shielding vault. The facility was installed and passed acceptance tests in September 2000, and has since been running mostly for machine development studies. The main parameters of the compact superconducting storage ring are given in Table 1. For further details see[1]

Fig. 1: Building of SSLS

Table 1: Main parameters of Helios 2 storage ring

Parameter	Unit	Value
Electron energy	MeV	700
Magnetic field	T	4.5
Characteristic photon energy	keV	1.47
Characteristic wavelength	nm	0.845
Electron current (typical)	mA	500
Circumference of electron orbit	m	10.8
Lifetime	h	>10
Emittance	µmrad	1.37
Source diameter horizontal	mm	1.45-0.58
Source diameter vertical	mm	0.33-0.38
Number of beam ports		20
Horizontal angular aperture/port	mrad	60

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Fig. 2: Helios 2 under test at the Oxford Instruments Ltd premises in Oxford, UK

Fig. 3: Helios 2 installed in the radiation shielding vault at SSLS

The bending spectrum generated by Helios 2 is depicted in fig. 4.

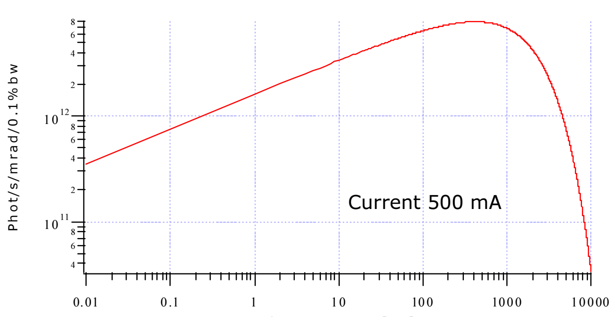

Fig. 4: Bending spectrum of Helios 2

2.2 Beam lines and experiments

The layout of the whole facility is shown in fig. 5. In the centre of the picture the 1.2 m thick concrete wall forming the vault can clearly be seen. Inside the vault, there are the Helios 2 storage ring as already mentioned and the 100 MeV injector microtron with the transfer line. Up to 20 ports are provided for beam lines. Their radiation is fanning out tangentially from either of the two 180° bends. Six of those ports are represented with beam lines attached, namely the LiMiNT for micro/nanolithography with the scanner located in a clean room of class 1000, the PCI for phase contrast imaging, the SINS for surface, interface, and nanostructure science in the VUV and soft X-ray range, the ISMI for infrared spectro/microscopy out to the far infrared, and the XDD and µXRF for X-ray diffraction, absorption, and fluorescence from 1.4 up to about 10 keV. The beam line status is summarised in Table 2.

2.3 Microtron Undulator Radiation Facility

Helios 2 is injected from a 100 MeV racetrack microtron. As this injector is most of its time idle it is planned to be used as a driver for the Microtron Undulator Radiation Facility (MURF). The 100 MeV electron beam of the microtron is passed through a superconductive miniundulator thereby generating highly brilliant synchrotron radiation and then deflected into an electron beam dump within the shielding vault. The photon beam generated in the undulator is transported through the shield wall into an experimental station. The period length of the supramini is 14 mm, number of periods 50, maximum magnetic field 1.5 T, and, accordingly, the

Table 2: Beam lines overview

Name	**Method**	**Spectral range (keV)**	**Status**
PCI	Phase contrast imaging	<10	Commis-sioning
LiMiNT	Micro/nano lithography	1 - 5	Delivery 10/01
SINS	Surfaces/ interfaces/ nanostructures	0.05 – 1.2	Delivery from 1/02
XDD/ µXAS	Diffraction/ absorption spectroscopy	1.4 - 10	Delivery from 1/02
ISMI	Infrared spectro/ microscopy	10^4– 10 cm^{-1}	funded
µXRF	Fluorescence	1.4 - 10	planned

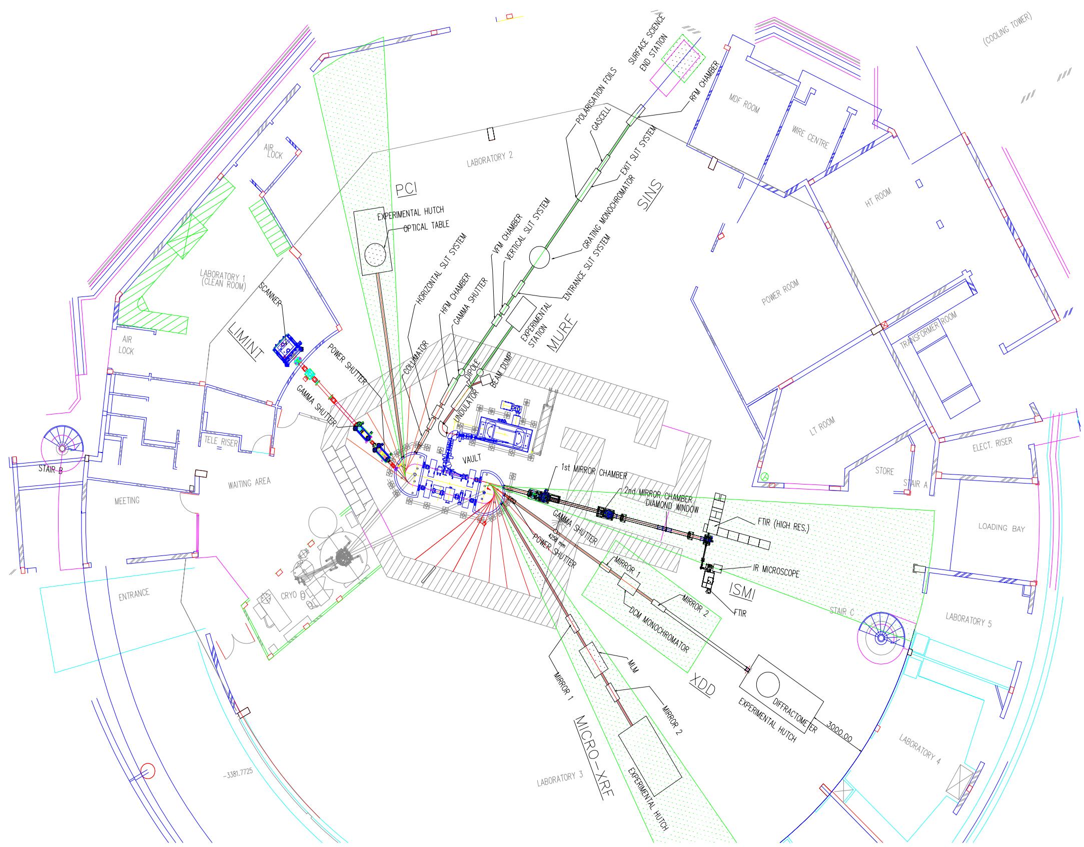

Fig. 5: Layout of SSLS

maximum value of the undulator parameter K=2. In this way, full tunability over a range from about 2 to 50 eV is possible. Being the lead time item the cold mass of the supramini has been contracted.

Fig. 6 displays the brilliance tuning curves of the MURF supramini as compared with the Helios 2 bending spectrum. MURF is more than one order of magnitude more brilliant, however, its radiation is not quasi cw as that of Helios, but pulsed with a duration of about 0.5 µs and a repetition rate of up to 10 Hz. MURF radiation complements Helios 2 towards the VUV range for surface and materials science.

3 STRATEGIC PLANNING

SSLS' R&D activities rest on three pillars, namely micro/nanofabrication, (nano)analysis, and the development of advanced synchrotron radiation equipment (fig. 7).

In the field of micro/nanofabrication, a number of 13 projects has been approved extending into fields such as biotechnology, microfluidics, micro/X-ray optics, and gigascale packaging and interconnects.

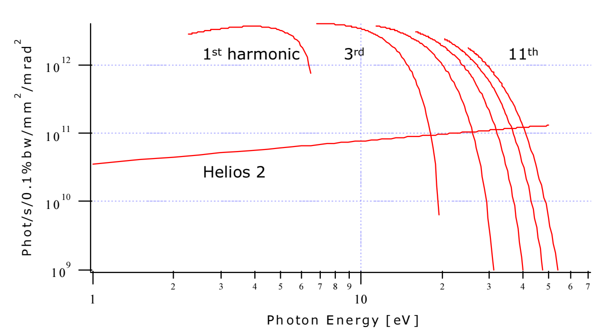

Fig. 6: MURF brilliance tuning curves compared with Helios 2 bending spectrum

Work on the analytical applications has started with phase contrast imaging and will be extended to projects in various fields including surface science, catalyst development, semiconductor process technology, combustion processes, astrophysics, biology, and materials science.

For both, micro/nanofabrication and the analytical applications, further development strongly depends on demand from the user community including universities, research institutes, and industry.

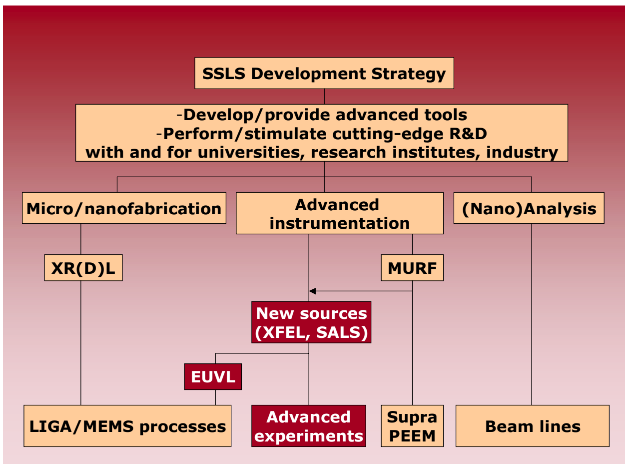

Fig. 7: SSLS' development strategy

The development of advanced instrumentation for synchrotron radiation has the clear perspective of opening up new opportunities in nanoscience and nanotechnology. A near-term goal of the MURF facility is to improve resolution of the photoelectron emission microscope (PEEM) that is an important tool for nanoscience. In this case, the tunable narrow band radiation of MURF will be used to irradiate the sample. On a longer time horizon the MURF facility is planned to be a stepping stone on the way to an X-ray Free Electron Laser based on superconductive miniundulators. This would open up advanced techniques such as soft X-ray photon-in photon-out experiments no longer needing UHV sample environment or a comprehensive single nano particle diagnostics. This development would also leed to an EUV FEL that would be needed very much in case wafer manufacturers adopt EUV lithography as their next generation lithography for making the chips of the future[2]. A possible sequence of development steps is given in Table 3.

Table 3: From MURF to the XFEL

Accelerator type	Electron energy	Photon energy
Microtron (MURF)	0.1	2 – 50 eV
Linear accelerator	0.25	12 – 300 eV
Recirculating linac	0.5	48 – 1200 eV
Recirculating Linac (XFEL)	2	1 – 19.2 keV <370 eV (coherent)

4 SUMMARY

Pilot user operation at SSLS, based on the compact superconducting Helios 2 storage ring, has started in October 2001 with the phase contrast imaging beam line. Further beam lines for micro/nanolithography, surface/interface/nanostructure science, X-ray diffraction and absorption, and (far)infrared spectro/microscopy will become available within 2002. The Microtron Undulator Radiation Facility (MURF) is planned to produce highly brilliant narrow band radiation in the VUV. The facility will be increasingly used for various projects in micro/nanofabrication, for analytical applications, and for the development of advanced synchrotron radiation tools.

REFERENCES

[1] V.C. Kempson, Chew Eh Piew, Tun Nyunt, Li Zhiwang, Yang Ping, H.O. Moser, I.J. Underhay, "Commissioning and Subsequent Performance Enhancements to the High Flux Synchrotron Radiation Source Helios 2 at the SSLS", APAC'01, Beijing, September 2001.

[2] G. Dattoli, A. Doria, G.P. Gallerano, L. Giannessi, K. Hesch, H.O. Moser, P.L. Ottaviani, E. Pellegrin, R. Rossmanith, R. Steininger, V. Saile, J. Wuest, "Extreme Ultraviolet (EUV) Sources for Lithography based on Synchrotron Radiation", Nucl. Instr. Meth. A, in press.