A brilliant light source rises in South-East Asia

The use of local expertise and a challenging construction site represent just two of the interesting characteristics of a project to build a new 3 GeV light source in South-East Asia.

The National Synchrotron Radiation Research Center (NSRRC), situated about one hour's drive from Taipei, has begun the construction of its second synchrotron-light source, the Taiwan Photon Source (TPS), with a ground-breaking ceremony that took place on 7 February. Like any other large-scale project, reaching this milestone involved years of preparation and intense decision-making. The project requirements left little room for even small deviations from delivery timetables or for cost increases. To meet its mandate on time, the NSRRC has relied on its experienced staff members, many of whom had previously participated in the construction of the Taiwan Light Source (TLS) in 1983 – the first accelerator at NSRRC. This is allowing the project to meet challenging deadlines and to transfer expertise to younger engineers.

The TPS is a $210 million project involving, at various times, more than 150 staff in charge of design, construction, administration and management of day-to-day operations. The official proposal for the TPS was submitted in 2006 and primary funding was provided by the National Science Council over a seven-year period, with $54 million for civil construction backed by the Council for Economic Planning and Development. Conceptual designs of the major systems were completed in 2009 and key systems are currently under construction. These include the linac, the cryogenic system, the magnets and the RF transmitters.

The TPS will be equipped with a 3 GeV electron accelerator and a low-emittance synchrotron-storage ring 518.4 m in circumference (see table). This will be housed in a doughnut-shaped building, 659.7 m in outer circumference, next to the smaller circular building that houses the existing 1.5 GeV accelerator, the TLS. The dual rings will serve scientists from South-East Asia and beyond who require an advanced research facility for conducting experiments with both soft and hard X-rays.

Design parameters of the TPS

Energy: 3 GeV
Brilliance: ~10^{21} photons/s/mm^2/mrad^2/0.1%($\Delta\lambda/\lambda$)
Maximum beam current: 500 mA
Horizontal emittance: 1.6 nm-rad
Storage-ring circumference: 518.4 m
Straight sections: 6 × 12 m + 18 × 7 m
Unit cells: 24 double-bend achromats
Beam lifetime: >10 hours
Operation mode: Top-up
Insertion devices: 6 (phase I)

The storage ring

The TPS storage ring comprises 24 bending sections, 6 long straight sections and 18 short ones. A mock-up of a unit cell representing 1/24 of the storage ring has been constructed to test all systems before mass production, including the 14-m long vacuum pipe, prototype magnets and girders. This mock-up will be useful for evaluating and correcting – if necessary – specific design decisions. It has also served as a case study for the Machine Advisory Committee that reviewed the status of the TPS from technical and scheduling standpoints. One significant benefit gained from such a mock-up is that it allows for the spatial study of components that fit closely together, as well as of the cables and piping.

The vacuum chambers are made of aluminium alloy, based on the merits of lower impedance, lower heat resistance and its outgassing rate. There are two bending chambers per unit cell, each 4 m in length with, in some places, a 1 mm gap to the adjoining sextupole magnet in a bending section. In total there are 48 such units in the storage ring, with walls typically 4 mm thick in the straight sections. The beam pipes are made from aluminium extrusions with two cooling channels on each side. There are also several long vacuum chambers to cope with undulators installed between the magnet poles.

Frome vacuum to RF

A 14-m long vacuum pipe was produced as part of the 1/24 mock-up. Foreseeable production challenges include the development of machining and cleaning, of welding and cooling systems for the bending-chambers, and of a means to transport the finished product from the assembly site to the TPS storage ring. To minimize the mechanical distortion caused by thermal irradiation of the vacuum chambers, cooling-water channels are attached on both sides of the pipe and where the beam-position monitors (BPMs) are located. To transport the 14-m long vacuum pipe, a "hanger" of equivalent size was built to carry the assembled unit. A successful rehearsal, mov-

A model showing the location of the TPS (the big ring) adjacent to the existing, smaller TLS (north is to the left). (Photos courtesy NSRRC.)

A complete mock-up of 1/24 of the storage ring was built for tests.

ing the transportation gear along 8 km of busy streets took place in March. The next step will be to ensure that no damage occurs to the vacuum pipe during the process.

To achieve optimal performance, the TPS accelerator will be mounted on metal girders placed on pedestals that can be adjusted via remote-control. The mock-up has demonstrated the sophistication reached in the design of these girders. Metal girders often suffer from rather low eigenfrequencies compared with concrete girders, especially when heavy magnets are placed on them. The TPS girders, however, are very stiff, which pushes up the eigenfrequencies. Measurements so far are in close agreement with predicted performance.

The TPS is designed for "top-up" operation, which is the standard operation mode in the TLS. The TPS injector complex will consist of a 150 MeV linear accelerator and a full-energy booster that will share the tunnel with the storage ring. Because this is a new facility with a low-emittance injector, the opportunity exists for using pulsed multipole injection, which may have significant benefits for quiet top-up. To allow acceptance tests of the linac before the storage-ring tunnel becomes available, construction work is under way on a bunker that will see future use for a Free-Electron-Laser (FEL) injector test facility.

Each of the 24 achromatic bending sections (unit cells) in the TPS contains 2 dipoles, 10 quadrupoles and 7 sextupoles. A further 168 skew quadrupoles, 1 injection septum-magnet and 4 kicker magnets, bring the total number of magnets to be installed to 629. All of the magnetic cores are made of silicon-steel sheet. The shaping of the iron laminations are made by wire cutting with computer numerical control machines to within 10 μm accuracy and are shuffled to ensure uniform magnetic properties. Accuracy in the magnet assembly is to be controlled to within 15 μm. The upper half of the magnet can be removed to install the vacuum chamber and the whole magnet can be detached without removing the vacuum chamber. The entire design for the magnet was performed in house with prototypes produced during phase I for thorough testing and measurement.

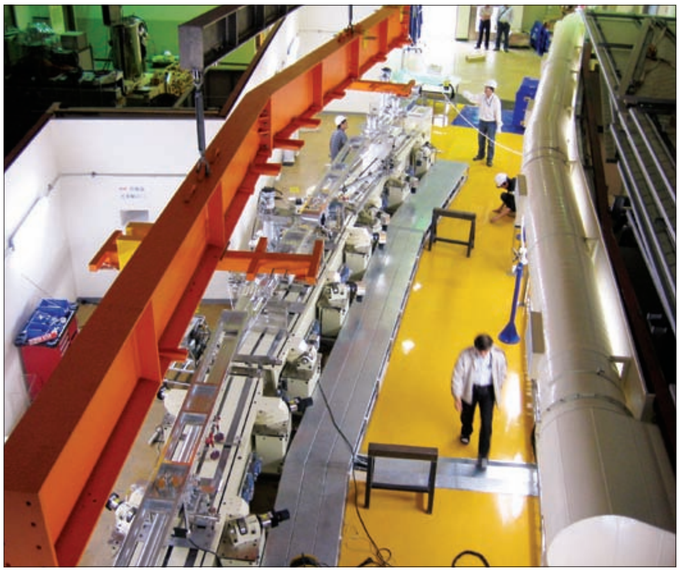
The TPS adopts the KEK approach to superconducting RF (SRF) to cope with future operational modes. Collaboration and technology transfer on the 500 MHz SRF module, as used at KEK for KEKB, is a de facto requirement to ensure the timely development of the SRF modules (including the 1.8 K cryostat for the harmonic SRF modules) and of technology-transfer for a higher-order-mode damped superconducting cavity suited to high-intensity storage rings. Conventional PETRA-type cavities will be considered as an alternative for commissioning in case the SRF cavities are not available in time.

Construction challenges

The complexity and cost of constructing a new accelerator facility adjoined to an existing one is much higher than for one built on undeveloped land. However, to optimize resources and personnel, and the use of common equipment, as well as to allow a versatile research facility for users of both accelerators, the decision was taken to build the TPS at the NSRRC home base.

The site slopes down from south to north and abruptly descends 5 to 10 m at the northern edge, where the TPS will be built. The geology around the site is simple with gravel as the main formation. Ideally, the platform for the storage ring would be created above ground or by digging underground. The first approach is expensive and risks instability in an area known for frequent earthquakes; the latter will magnify the humidity problems in land soaked with rain and may cause a partial, if not total, subsidence of the existing TLS. To keep the civil construction cost within budget, the solution has been to meet both alternatives half way. The TPS storage-ring building will have its floor at the beamline area 12.5 m underground near the south side, and 4 m above ground at the north side. A beamline for medical imaging will be located on the west side next to the busiest traffic of the Hsinchu Science Park, while beamlines demanding nanoscale resolution will be located away from the possible sources of vibration.

Building a new accelerator next to an existing one involves continual challenges. Because the TPS building cuts into the edge of the TLS, the prevention of instability and vibration in the TLS caused ▷



A 14-m long "hanger", equivalent in size to the vacuum chamber, was built to carry the assembled unit.

Walls of the TLS building were torn down for the new interface with the TPS storage ring and piles were inserted to stabilize the TLS foundations.

by the construction work is a critical issue. To prepare for this daunting task, the NSRRC held workshops on ambient ground motion and civil engineering for the TPS in 2005 and 2008, so as to study the methods and strategic solutions used at other synchrotron facilities. These resulted in mechanical approaches to eliminate or reduce amplification of the floor motion by the girder system for the TPS, while also adding steel piles to prevent the adjacent TLS foundations from gradually crumbling.

Various methods to protect the TLS foundations and building centre on supporting the ground soil with *in situ* reinforcing and shoring-up the longitudinal sections that are exposed by excavation work. Taking advantage of the fact that the site is mainly of gravel formation, the TLS beam columns were reinforced with additional frames. In addition, seven H-beam, Type-L steel piles, 17.5 m long, were inserted in places where parts of walls of the TLS storage ring previously stood. Each pile was also equipped with a 200 cm × 120 cm × 60 cm concrete beam laid horizontally against the TLS foundations. These piles provide pressure to prevent the TLS from rising through elastic deformation occurring when the suppression disappears as a result of the 10 m-deep excavation.

To meet the target milestone of commissioning by the end of 2013, civil construction and accelerator installation will proceed concurrently. Partial occupancy of the linac building and ring tunnel needs to occur by the beginning of 2012 to meet the installation timetable for ring components. Power and other utilities will be brought in once pedestal paving and the installation of piping and cable trays begins. This will allow the setting up of the booster ring and subsystems in the storage ring. The SRF cavity will be the final component to move in and tests for TPS commissioning will follow accordingly.

With the accumulated expertise from the past, the design of the TPS has been achieved by the NSRRC's own members. With their capability in developing insertion devices for the TLS and systems to cope with their operation established since 1993, the photon energy of the TPS should reach 30 keV. With a maximum brightness of 10^{21} photons/s/0.1%BW/mm^2/mrad^2 at 10 keV it will be among the brightest light-sources available.

Résumé

Et la lumière fut en Asie du Sud-Est

Le NSRRC, le centre national taïwanais de recherche sur le rayonnement synchrotron, a commencé la construction de sa seconde source de lumière synchrotron, nommée Taïwan Photon Source (TPS). À l'instar d'autres programmes de grande envergure, des années de préparation et de processus décisionnels ont été nécessaires pour atteindre cette étape cruciale. Pour respecter les échéances, il a fallu considérablement solliciter du personnel expérimenté qui avait déjà participé à la construction du premier accélérateur du NSSRC, Taiwan Light Source (TLS), en 1983. Ainsi, le projet a su tenir des délais ambitieux et a permis le transfert de connaissances à de jeunes ingénieurs.

Diana Lin *and* **Gwo-huei Luo**, *National Synchrotron Radiation Research Center.*

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