

# Diamond Light Source Proceedings

<http://journals.cambridge.org/DLS>

Additional services for *Diamond Light Source Proceedings*:

Email alerts: [Click here](#)

Subscriptions: [Click here](#)

Commercial reprints: [Click here](#)

Terms of use : [Click here](#)

---

## Mechanical design and analysis of in-vacuum undulators at the Shanghai Synchrotron Radiation Facility

Z. Jiang, H. Du, C. Chen, Y. Fan and X. Wang

Diamond Light Source Proceedings / Volume 1 / Issue MEDSI-6 / October 2011 / e20  
DOI: 10.1017/S2044820110000286, Published online: 26 October 2010

**Link to this article:** [http://journals.cambridge.org/abstract\\_S2044820110000286](http://journals.cambridge.org/abstract_S2044820110000286)

### How to cite this article:

Z. Jiang, H. Du, C. Chen, Y. Fan and X. Wang (2011). Mechanical design and analysis of in-vacuum undulators at the Shanghai Synchrotron Radiation Facility. *Diamond Light Source Proceedings*, 1, e20 doi:10.1017/S2044820110000286

**Request Permissions :** [Click here](#)

## Poster paper

# Mechanical design and analysis of in-vacuum undulators at the Shanghai Synchrotron Radiation Facility

Z. JIANG<sup>†</sup>, H. DU, C. CHEN, Y. FAN AND X. WANG

Shanghai Institute of Applied Physics, Shanghai 201800, People's Republic of China

(Received 20 June 2010; revised 30 August 2010; accepted 22 September 2010)

Two in-vacuum undulators (IVU25) have been used since March 2009 at the Shanghai Synchrotron Radiation Facility. Another small-gap in-vacuum undulator with a smaller period length of 20 mm was completed in July 2010. The mechanical system of IVU25 consists of support frame, driving and guiding system, taper mechanism, compensation spring system, suspending rods assembly, etc. We have attempted to manufacture IVU25 with high mechanical stability, rigidity and reproducible gap motion. A mechanical design study of IVU25 is carried out which includes finite-element calculations on the mechanical deformation of the girder. Some modifications have been made to the design of IVU20.

---

## 1. Introduction

Shanghai Synchrotron Radiation Facility (SSRF) is a third-generation synchrotron light source (Xu and Zhao), with energy 3.5 GeV, circumference 432 m and current up to 300 mA, and has been opened to users in May 2009. It has 20 straight sections for the installation of electron-beam injection, radio frequency and insertion devices. In Phase-I of SSRF, seven beamlines and five insertion devices were built, including two wigglers, one elliptically polarizing undulator (EPU100) and two in-vacuum undulators (IVU25). Two in-vacuum undulators with the same design of period length 25 mm and minimum gap 7 mm can cover the photon energy range of 3.5–22.5 KeV up to the 11th harmonic and are used for the macromolecular crystallography station and the hard X-ray micro-focus station, respectively (Qiaogen). A new in-vacuum undulator with period length 20 mm and minimum gap 5 mm has been completed for the Pohang Light Source at SSRF. IVU25 requires a highly reproducible gap motion and mechanical stability to produce light of high quality. Table 1 shows the key numbers which have great impact on the mechanical design.

## 2. Mechanical design

For the structure of the main-frame body, IVU25 adopts the C-type, despite the H-type having superior mechanical properties (Chang *et al.* 2008). Figure 1 presents

<sup>†</sup> Email address for correspondence: jiangzhiqiang@sinap.ac.cn

Minimum/max. gap/mm	7~25
Maximum magnetic force load/kN	10
Maximum girder deformation/ $\mu\text{m}$	$\leq \pm 3$
Gap adjustment accuracy/ $\mu\text{m}$	$\leq 1$
Taper control/ $\mu\text{m}$	$\leq \pm 2$
Vertical alignment accuracy/ $\mu\text{m}$	$\leq \pm 160$
Horizontal alignment accuracy/ $\mu\text{m}$	$\leq \pm 500$

TABLE 1. Mechanical requirement and specification of the IVU25.

the two-dimensional view of the IVU25 that includes all components – adjust system, base plate, support frame, driving and guiding system for gap change, encoder system, out-vacuum girder, compensation spring system and in-vacuum system designed by the vacuum group.

There are two work patterns for IVU25; one is the taper pattern and the other is the non-taper pattern. It is necessary to design a taper mechanism to meet the needs. As shown in figure 2, the out-vacuum girder is supported by two overhanging shafts. One is bolted to the ram on the upstream and the other is connected to the ram by tangent motion mechanism which can move along both horizontal and vertical directions on the downstream. The taper mechanism could allow a reproducible mechanical gap taper in the range of 1–500  $\mu\text{m}$ . In addition, the taper mechanism, limit switch and gap motion stopper play an important role in the protection of the IVU25 in the case of loss of driving control.

### 3. Girder analysis

The purpose of engineering calculation is to estimate the deformation of the out-vacuum girder. For high-performance magnetic field, the mechanical structure must be in accord with the above requirements and be strong enough to be equipped with the magnet arrays.

The out-vacuum girder is reduced to an extensional beam mode shown in figure 3, when 6 m is equal to  $\sqrt{6}l$ , the deformation of the beam is in its maximum value

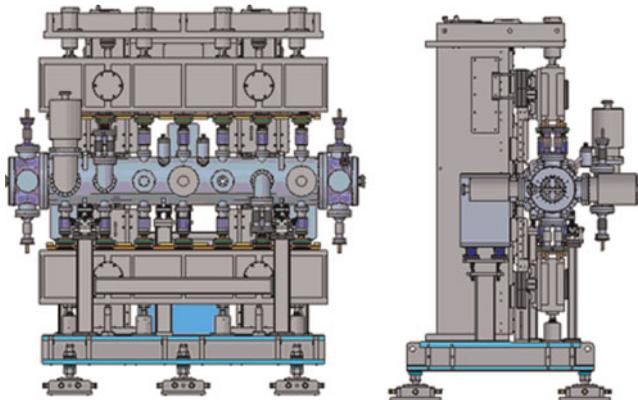


FIGURE 1. Two-dimensional views of the IVU25.

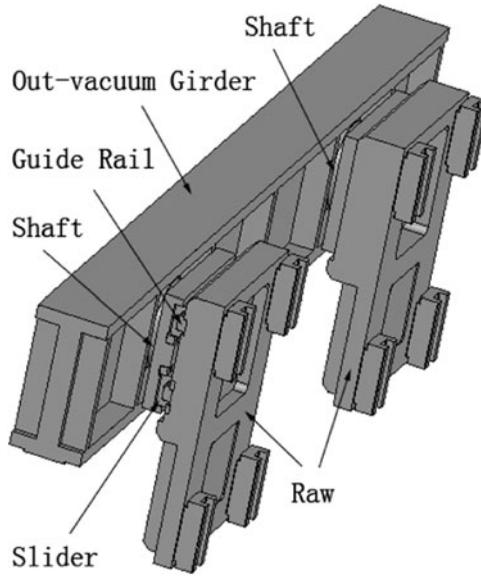


FIGURE 2. Taper mechanism.

which can be expressed as

$$f = \frac{q \cdot l^4}{384 \cdot E \cdot I}$$

where  $f$  is the deformation,  $q$  is the load per unit length,  $E$  is the modulus of the elasticity,  $I$  is the moment of the inertia and  $l$  is the distance of two support points. For IVU25, the maximum magnetic force under gap 7 mm is about 10 kN. According to the above equation, the deformation of the upper out-vacuum girder under worst conditions is  $2.97 \mu\text{m}$  that is consistent with the specification. Besides, the deformation of the lower out-vacuum girder is less than  $3 \mu\text{m}$  because the weight force compensates part of the magnetic force on the lower girder.

#### 4. Conclusions

Two IVU25s were installed in the storage ring of SSRF and have been under operation without any difficulty. The mechanical performance of the IVU25 meets the station's specifications with good margins. In order to do better, we have to modify the design of the IVU20, for example, to replace the ball bearing with linear bushing. Nevertheless, the diameter of the overhanging shaft is enlarged. In the process

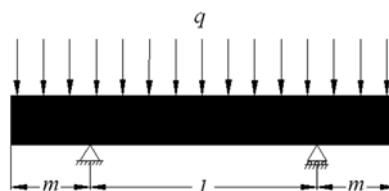


FIGURE 3. Schematic diagram of a uniformly loaded extensional beam.

of shimming, we find that some mechanical performances of IVU20 are better than that of IVU25.

### Acknowledgements

This work was partly supported by the National Nature Science Foundation of China under Grant No. 10805072.

### REFERENCES

- CHANG, C.-H., HWANG, C. S., CHANG, C. H., CHEN, H. H. & HUANG, M. H. 2008 Design concept for a standard C-frame support structure for insertion devices. Mechanical Engineering Design of Synchrotron Radiation Equipment and Instrumentation (MEDSI), Saskatchewan, Canada.
- XU, H. J. & ZHAO, Z. T. 2008 Current status and progresses of SSRF project. *Nucl Sci Tech*, **19**, 1–6.
- QIAOGEN, Z. 2009 Undulator development for SSRF, 2009.12. <http://www.sinap.ac.cn/meeting/EFST2009/142nd-EFST/EFST-Zhou Qiaogen.pdf>.