A New Generation of an In-Vacuum, Cryogenic Elliptical-Polarization Undulator (Cryo-EPU)

Joe Kulesza[a] , Dave Waterman[a], Alex Deyhim[a], K. Ingvar Blomqvist[b], Roger Carr[c]
[a] *Advanced Design Consulting USA, 126 Ridge Road, P.O. Box 187, Lansing, NY 14882; adc@adc9001.com*
[b] *Kyrkebyn, Brunskog194 Sweden,* [c] Stanford Synchrotron Radiation Laboratory, Stanford Linear Accelerator, Stanford, CA 94309

This publication describes an Apple/EPU type Cryogenically-Cooled Permanent Magnet Undulator. It has been recently discovered that magnetic materials like NdFeB have about 25% stronger remanent fields and 3-5-fold higher coercivity as the temperature is lowered. Higher coercivity usually means lower remenance, so the best types of NdFeB can not be used for in-vacuum undulators due to degradation in radiation and at UHV bakeout temperatures. Cooling the magnets to increase coercivity allows higher remanence grades of NdFeB to be used, which, in addition, makes the fields stronger. For the exotic material PrFeB, this effect takes place at liquid nitrogen temperature. To make use of this effect, undulators must be cooled to cryogenic temperatures and in the cooled down state, magnetic measurements and adjustments of the PM must be performed.

Scientific Justification

Given the several million dollar expense of a typical beamline and the frequent heavy demand for user time, there is strong pressure to optimize the source. Generally, the preferred source is a magnetic insertion device located in a straight section of the storage ring, which are few in number and thus highly valuable. Especially for soft x-ray sources and uses, we propose here that the best x-ray source is an in-vacuum, variable polarization cryo-undulator. These three technologies would combine to create a source with the maximum flexibility and brightness possible with present technology. Let us discuss each of them briefly, in order.

For most experiments, brightness is most valued figure of merit. Higher values of Br allow more periods to be placed in the same straight section, thus creating more flux and brightness for the same energy range. The argument for in-vacuum insertion devices is all about minimizing the magnetic gap. The magnetic field of an undulator increases exponentially with smaller magnet gap. The gap of an out-of-vacuum device is restricted by the size of the beampipe, but the last decade or so has seen a strong growth of in-vacuum insertion devices, whose cost and complexity has been judged worthwhile in view of their resulting higher performance. One can obtain higher magnetic fields at a given magnet period length, thus allowing an undulator to provide a lower energy fundamental spectral peak. One can also install more periods in the undulator, and obtain more flux for a given spectral range. A combination of these strategies is normally used. Contemporary storage rings now allow minimum internal gaps in insertion regions on the order of 3.5-10 mm. Allowing for beampipe thickness and clearance, the corresponding minimum external gap is on the order of 8-15 mm, and often larger. For a given storage ring energy, only certain values of the lowest energy undulator fundamental may be of interest. If users have no use for, and beamline optics are not designed for radiation below a specified energy, then it makes sense to shorten the undulator period, put more periods into the insertion region, and maximize flux and brightness.

Proposed Design

Our concept for a Cryo cooled in-vacuum apple with small magnets is as follows: The magnet arrays are mounted using an array of flexures instead of bearings. The flexure geometry is such that the magnets still move in a linear fashion, not an arc. Flexure mounting allows the heat to pass from the magnets through the flexures similar to ADC's SL800 slits, the Cryo cooling tubes are not worked inside the vacuum, only up and down with straight bellows as was done for the BNL cryo-cooled undulator which was planar. The flexures have no moving parts that would need to be lubricated. The arrays have to move 1/4 period, which is not trivial.

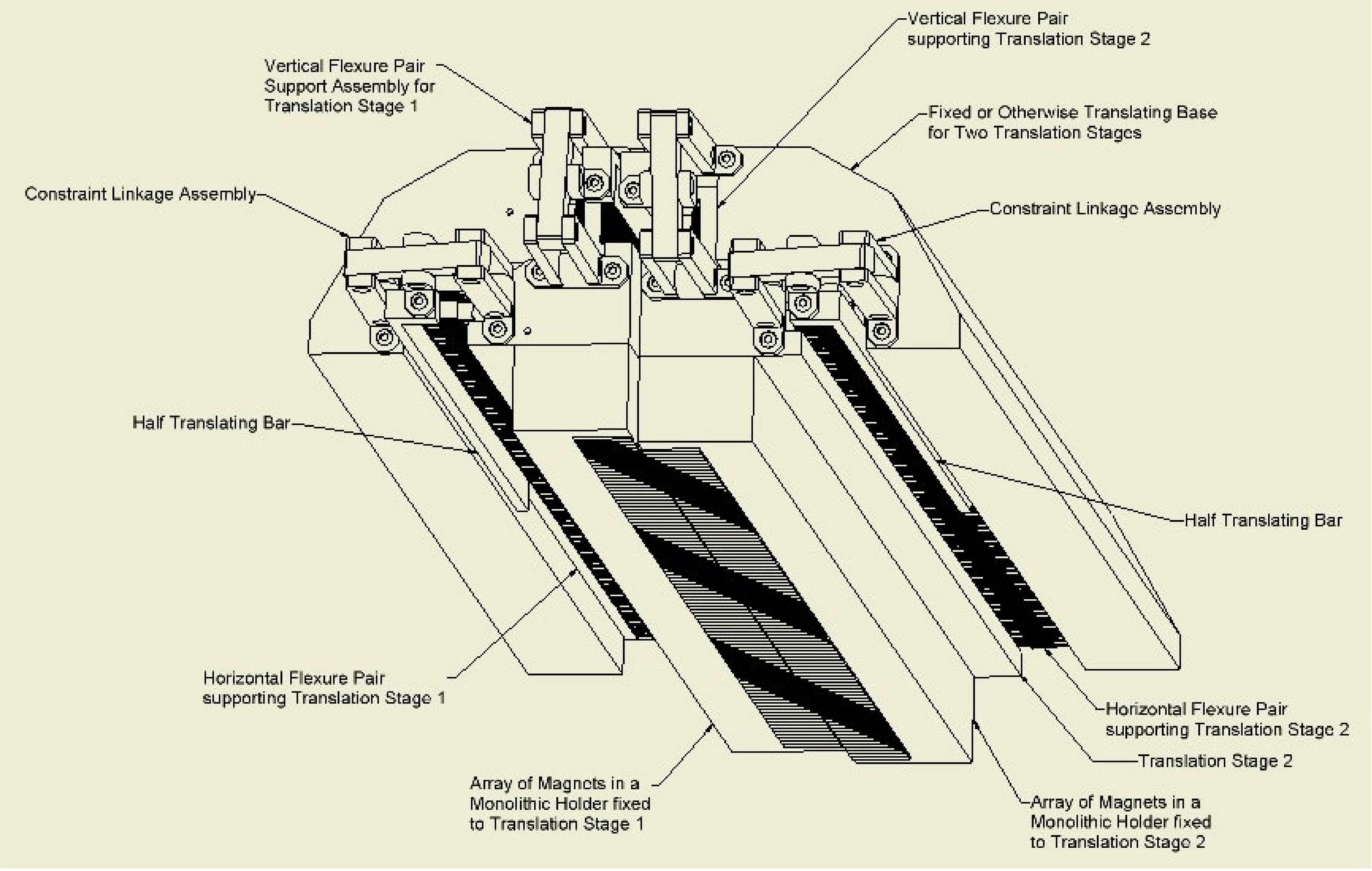
ADC's experience with APPLE/EPU devices, allows us to feel comfortable with this project. Careful attention must be paid to the temperature coefficient of the expansion of materials, and any effect this has on the mechanical alignment, magnet hold downs, etc. Careful attention must also be paid to the question of running costs; as it should have some reasonable insulation and heat barriers. Also, for example, we might avoid correction coils and go to permanent magnet correctors with mechanical actuators.

The challenges to development of this device technology include the following:

(1) Lubricant-free, ultra-high vacuum (UHV) compatible, linear-motion stages, capable of withstanding an extreme range of temperatures;
(2) Accommodation of large differential thermal expansion/contraction between the cold in-vacuum magnet arrays and the external vacuum chamber and support structure during operation, as well as during baking;
(3) Obtaining a reliable source of permanent magnet material capable of withstanding temperatures from below 130°K (-243°C) during cryogenic operation to over 100°C during baking, without loss of magnetization;
(4) Providing an adequate conductive path for electron beam image currents with minimal encroachment into the stay-clear aperture required by the electron beam.
(5) Working at 77 K would drastically simplify our design. However, PrFeB is a rather "exotic" material, and it would require some effort to reach the same standard of manufacturing as NdFeB, in particular concerning the important point of magnetic homogeneity. A strict collaboration with a qualified industrial manufacturer of permanent magnet materials would be beneficial for the success of the project.
(6) Another unsolved, perhaps the only real problem, is how to handle the (electron) image currents in an IVCC-EPU. In a planar device one uses full-width nickel foils, top & bottom, that "stick" to the magnet faces. But in an EPU these foils would be on sub-girder faces that are sliding in opposite directions ... and one generally does not want two foils top & two foils bottom with a seam above/below the beam in what is intended to be a small-gap device. This is our top engineering/technical challenge; the rest is marrying EPU & IV technologies.

Flexure Array Support for Linear Stage

The present invention relates to a suspension system for rigidly supporting a linearly translatable stage that is subject to a considerable variety of different forces acting upon it. The method uses two or more linear arrays of flexures connected to a fixed or independently translating base structure and also uses an additional flexure or pin linkage so as to limit movement of the flexure arrays to a mode that closely approximates linear translation. The structure of the system, and its connection to the movable structure and to the fixed or independently translating base structure, are such that the system prevents the transmittal of any rotational force from the fixed structure to the movable structure, and also limits the motion of the movable structure (with respect to the fixed or independently translating structure) to linear motion along one axis, within a small tolerance. This design is especially useful for translation stages inside ultrahigh vacuum chambers.



Advanced Design Consulting USA, Inc
www.adc9001.com
adc@adc9001.com
PO Box 187
187 Ridge Road
Lansing, NY 14882
USA

The 10th International Conference on Synchrotron Radiation Instrumentation
27 September - 2 October 2009
Melbourne, Australia