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Helical PPM undulator for ERL

Alexander Temnykh, LEPP, Ithaca NY, 14853

Abstract. The note describes conceptual idea for pure permanent magnet (PPM) undulator with helical magnetic field for generation of synchrotron radiation with variable polarization. The undulator geometry utilizes specific properties of ERL electron beam such as small transfer beam size and roundness. The note presents the possible range of the undulator characteristics calculated using 3-D magnet model.

Magnetic structure and magnetic field properties.

The PPM undulator consists of two pairs of magnetic arrays assembled from "delta"-shaped magnetic blocks as is schematically shown in figure 1.

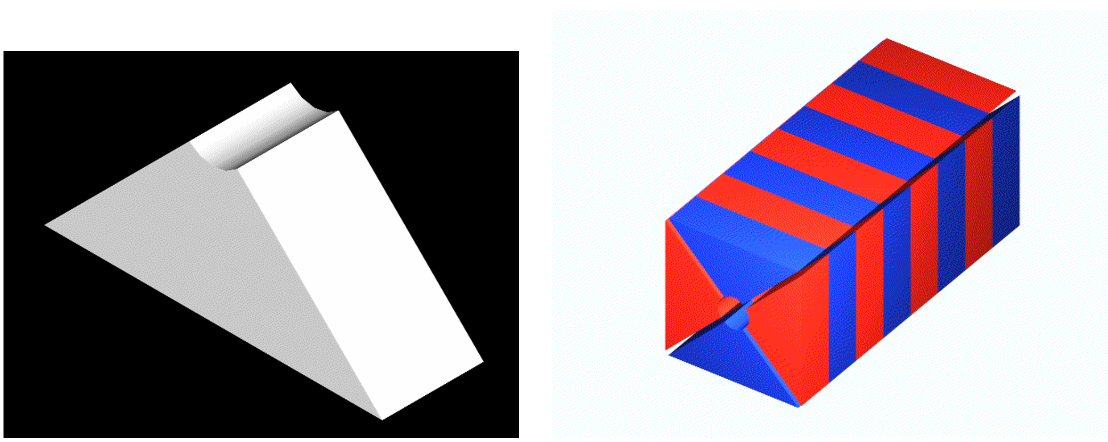

Figure 1. "Delta"-shaped PM block and two periods of undulator assembly. Different colors in assembly indicate magnetic blocks magnetized parallel and perpendicular to beam axis.

The first pair of arrays produces a periodic vertical magnetic field while the second pair produces a horizontal one. By moving the first array pair along beam axis relative to the second, one can change phase of vertical field relative to horizontal. This will change polarization of the generated radiation. By moving arrays away from beam axis one can change magnetic field amplitude. This will result in the change the energy of generated photons. Depending on requirement, undulator can be designed to operate in-vacuum. In this case, the bore radius can be smaller and field in the beam region stronger.

Below are given results of 3-D magnetic field calculation for such undulator with 4mm bore diameter and 24mm period.   NEOMAX – 42AH was used as the magnetic material, with Br = 1.3T and demagnetization temperature at "zero" field around 140deg C. Figure 2 depicts 3-D view of arrays generating vertical magnetic field.

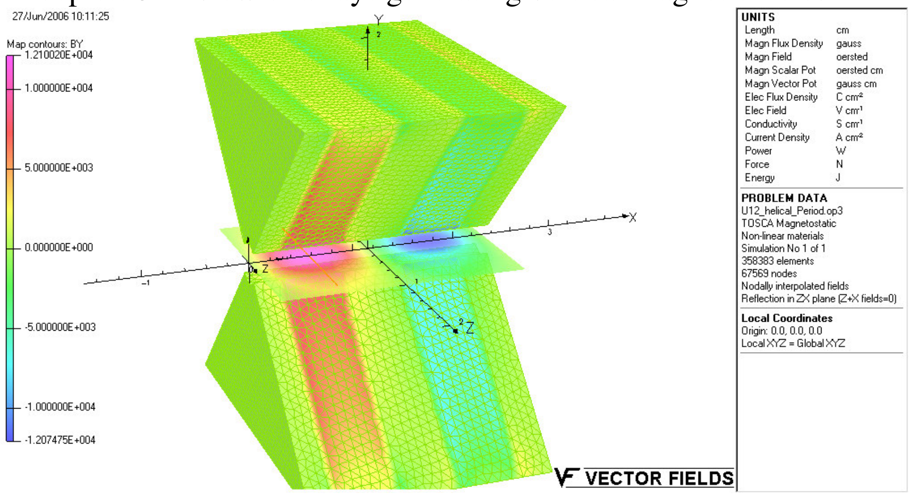

Figure 2. 3-D view of arrays generating vertical magnetic field, one period shown.

Dependence of the vertical component of the field on longitudinal and horizontal coordinates is given in Figure 3.

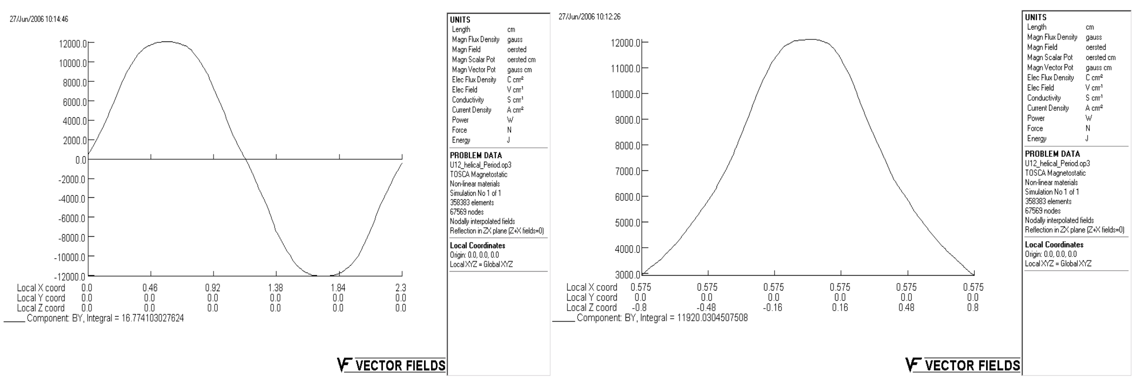

Figure 3. Vertical magnetic field along (left) and across (right) beam axis.

Figure 3 indicates a 1.27T peak field and +-1mm good field region around the beam axis. Both parameters, peak field and good field region, are better than for similar size Apple-II type undulator.

For future reference, Figure 4 gives calculated dependence of the peak field on undulator period. These calculations were completed with a 3-D model, and used magnetic material with Br = 1.3T (NEOMAX-42AH) and 4mm bore diameter.

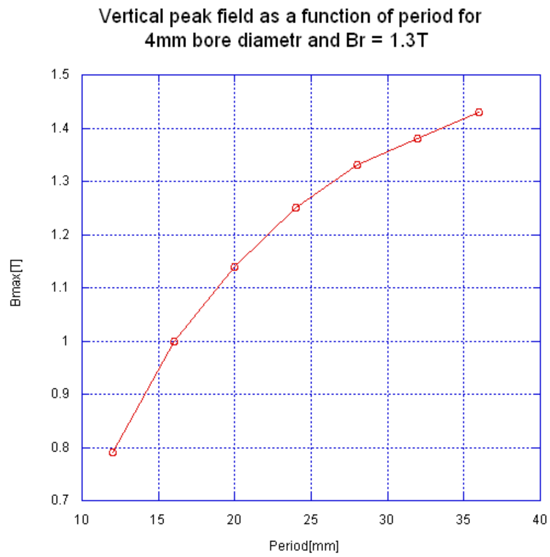

Figure 4. Peak field as function of period for 4mm bore diameter and magnetic material with Br = 1.3T (NEOMAX-42AH)

The spectral characteristics of the synchrotron radiation generated are discussed in the next section.

Spectral characteristics of radiation.

Spectral brilliance as a function of photon energy for 2.5m long, 4mm bore diameter, PPM helical undulators with different periods is given on Figure. 5. 5GeV ERL beam with 25mA of current, 0.008nm emittance and 2m beta function was used. All calculations were made with program "Spectra." For peak field, data presented in previous section was utilized.

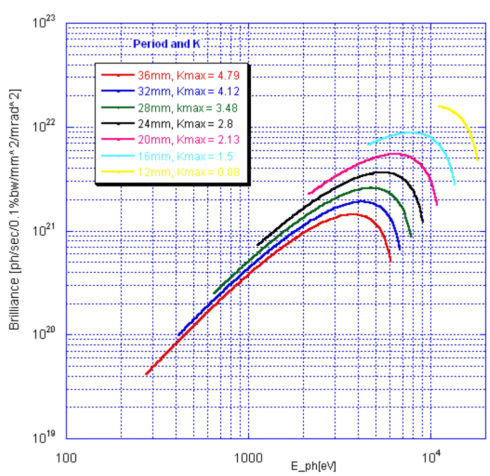

Figure 5. Tuning curves for 2.5m long, 4mm bore diameter PPM helical undulators.

Comparing curves with requirements for soft x-ray beam lines at "https://wiki.lepp.cornell.edu/lepp/bin/view/ERL/Private/ErlXrayWork" one can see that 24mm period PPM helical undulator producing photons in energy range from 1keV to 9keV range can be considered as a source for nanoprobe beamline #7.

To satisfy requirement of beamlines #4,5 and 6, photon energy from 100eV to 5keV, the period of undulator should be extended and the peak field should be boosted.

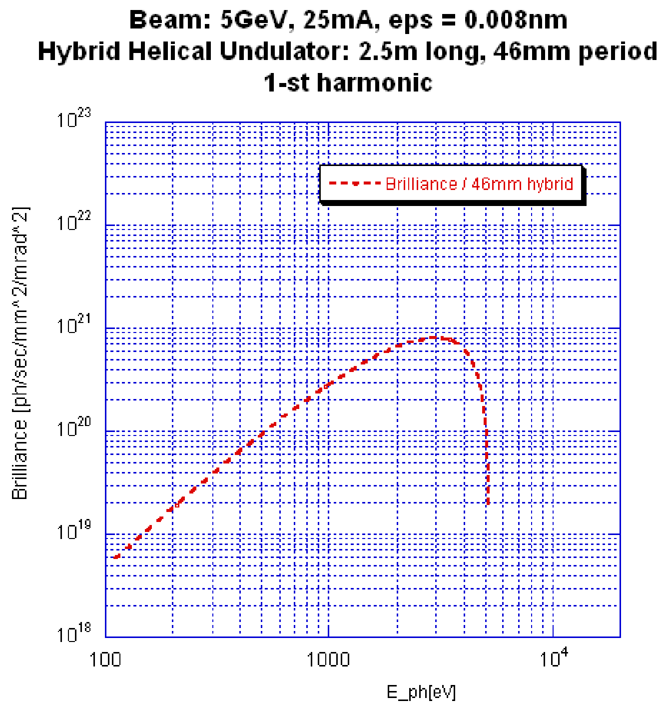

Figure 6. Spectral brilliance as function of photon energy for hybrid 46mm period helical undulator.

The latter can be accomplished by the insertion of ferromagnetic poles, i.e., switching to hybrid structure. Figure 6 gives example of the tuning curve for 46mm period, 1.6T peak field hybrid helical undulator with 4mm bore diameter. In this case the lowest photon energy is ~ 100eV and highest ~ 5keV. It will satisfy requirements of beam lines #4,5 and 6.

Conclusion

In the note a type of PPM helical undulator utilizing specific properties of ERL beam such as roundness and small transfer size was proposed. This type of undulator can produce a soft x-ray beam with variable polarization of energies suitable for ERL beamlines #4, 5, 6 and 7.