Superconducting elliptical undulator

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INTRODUCTION

Circularly polarized photons are widely used for conducting experiments to study the magnetic structures of matter. On the basis of superconducting coils developed at the Budker Institute of nuclear physics for a short-period superconducting planar undulator, a superconducting elliptical undulator with a period of ~2.2 cm and an elliptic coefficient of ~ 0.7 is proposed. The poles of the upper and lower halves of the undulator are located at an angle of 45 degrees to each other in the horizontal plane, which creates a periodic vertical and horizontal elliptical field of up to 1 T vertically and 0.7 T horizontally. There is a possibility to create a fast switching left and right polarizations of radiation at a zero angle from two sequentially installed undulators by quickly switching the electron orbit using correction magnets external to the cryostat (up to hundreds of Hertz). A short prototype of an elliptical superconducting undulator was made and magnetic measurements were made in the bath cryostat. The paper presents numerical calculations of the undulator fields, its spectra, and the experimentally measured field.

Superconducting elliptical undulator

The developed prototype of an elliptical undulator consists of 15 periods, 30 coils. Each period consists of a coil and a neutral pole. The structure of the undulator is designed so that all 15 periods of the top of the magnetic structure unfold at an angle of 45 degrees relative to the axis of the undulator, and the bottom, on the contrary, at an angle of -45 degrees. Each magnet due to this arrangement of the coil over its length meets an oppositely directed magnetic field, which creates another component of the magnetic field. As a result, the field has an elliptical structure with an ellipticity coefficient of 0.7.

Each coil is 11 mm wide, 85.5 mm long and 13.9 mm high. It is wound with the help of Nb-Ti wire with a diameter of 0.55 mm. The coil has 6 layers in width and 9-10 turns in height. A total of 57 turns with current.

The neutral pole has a width of 4.2 mm and is part of the yoke, consisting of a soft iron magnet.

As a result, the undulator period is 2.2 cm and the gap is 8 mm.

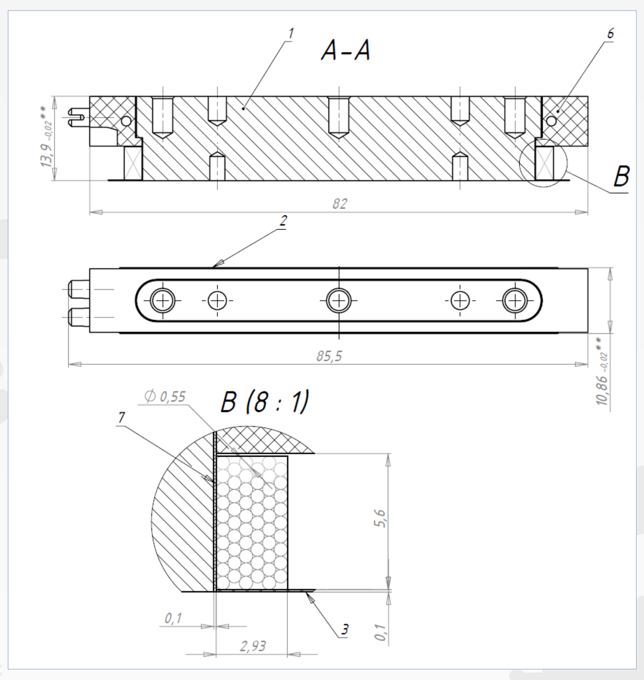

Figure 1: Design drawing of the coil

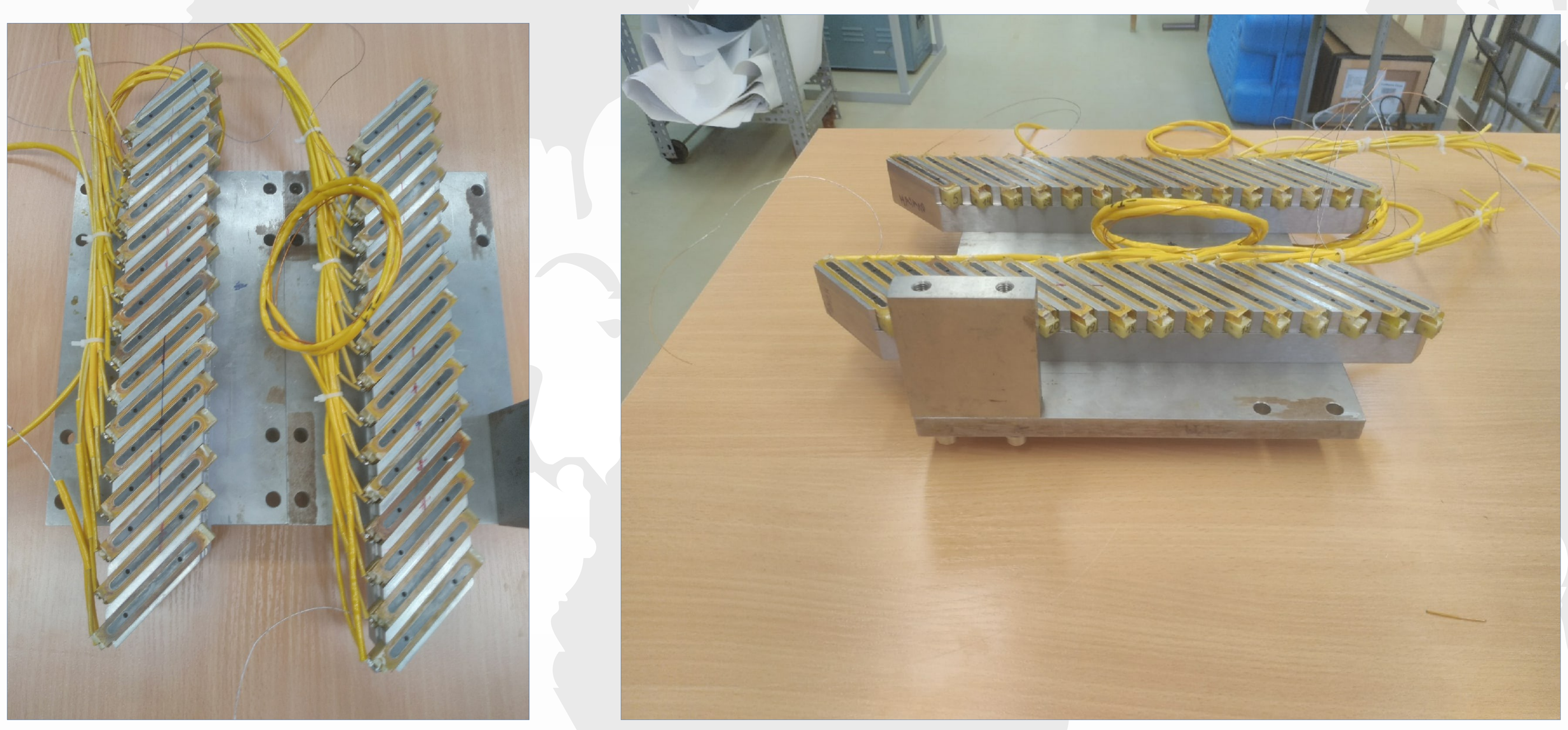

Figure 2: The prototype of a disassembled elliptical undulator. Upper and lower halves

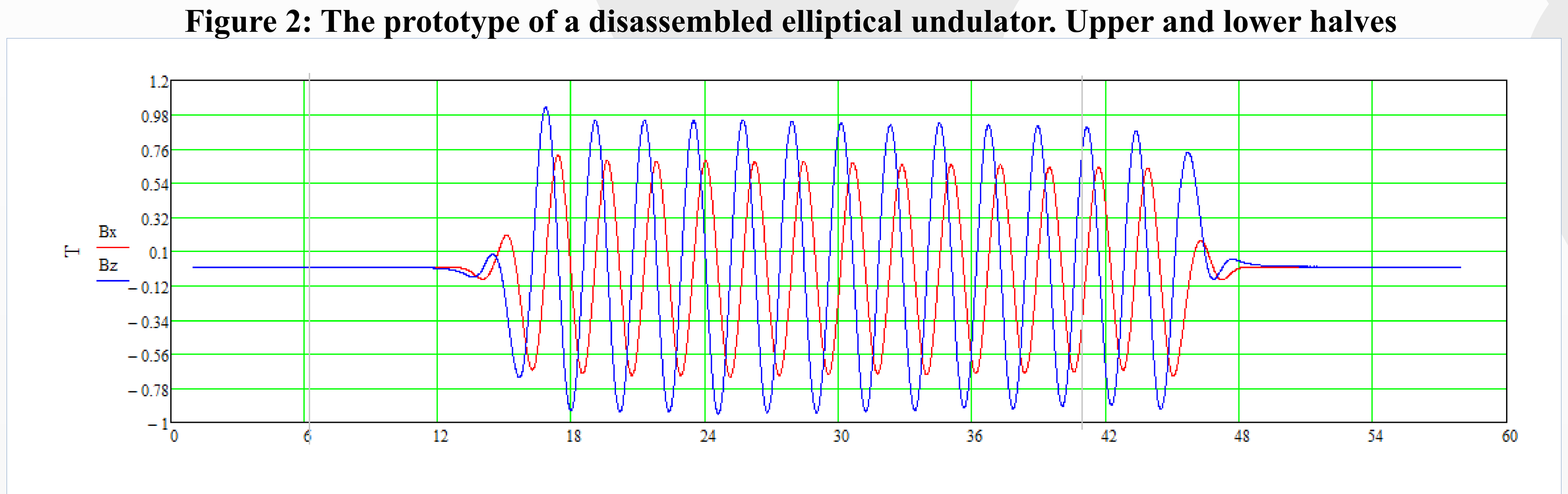

Figure 3:The magnetic field of the prototype undulator. Bz=1 T and Bx=0.7 T .

Magnetic measurements were made in an immersion cryostat, in liquid helium at a current of 460 amperes. The amplitude of the fields was 1 and 0.7 Tesla. The magnetic field was measured using a matrix of cryogenic Hall sensors PHE606118B and one vertically located Hall sensor Hgs-1050

Scheme of fast change of polarization of photons.

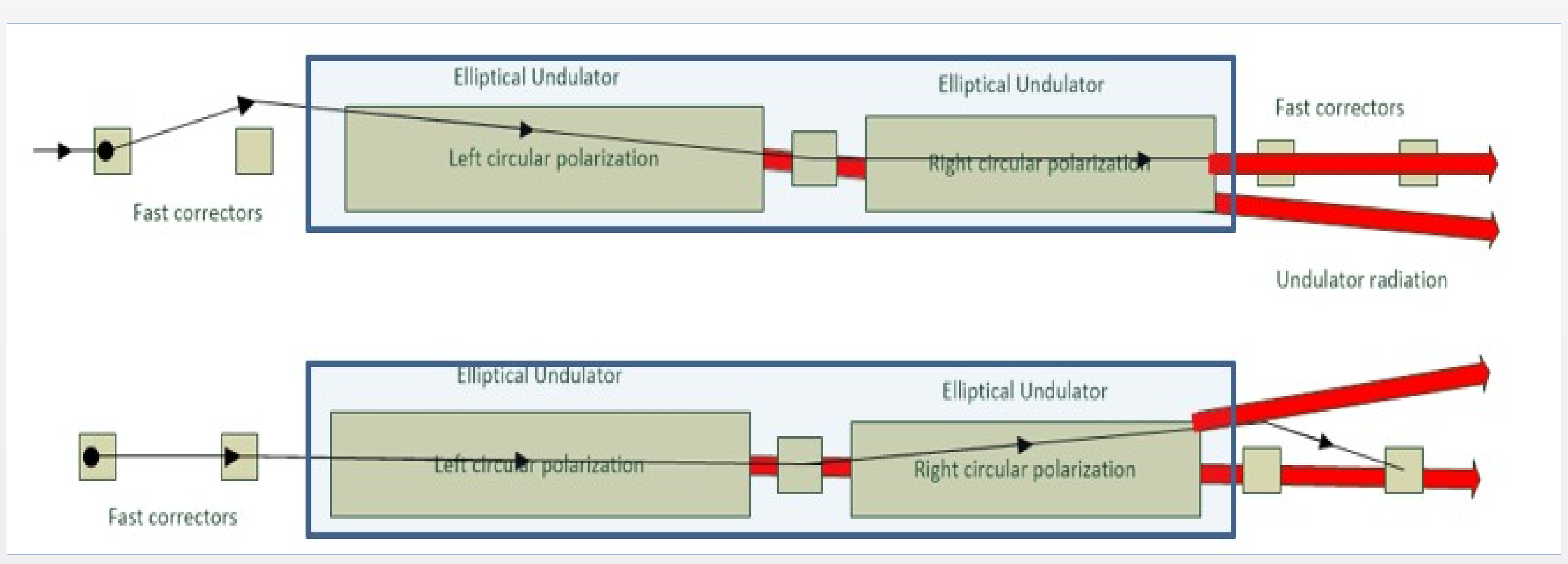

Figure 4: Scheme of fast change of polarization of photons

Using two such elliptical undulators, one can be manufactured with the ability to quickly switch polarization. Two undulators with different circular polarization of the magnetic field are installed in series with each other. To correct the orbit, 5 correctors are installed. 4 outside, 1 between undulators. These correctors serve to correct the flow of radiation directed at the user. 1 time then the photons from 1 undulator will fly after adjustment from 2 undulators. This scheme allows you to very quickly switch the polarization of light up to several kilohertz.

Modeling a real elliptical undulator.

To calculate the spectral properties of photons, a program was written in Mathcad to simulate the real conditions of an undulator. The simulation is based on the analytical formula of the magnetic field from a current conductor of finite length. The coil in this case is represented as the sum of the turns. One turn is represented as the sum of conductors with a current of finite length. The result was an undulator 2m long, 90 periods, with a gap of 8 mm, and a magnetic field, 1 and 0.7 Tesla. The program used a current of 480 amperes, limited by the critical characteristics of the superconducting wire. The length of 2 meters was chosen on the basis of the fact that this is the standard size of manufactured undulators at the Institute of Nuclear Physics.

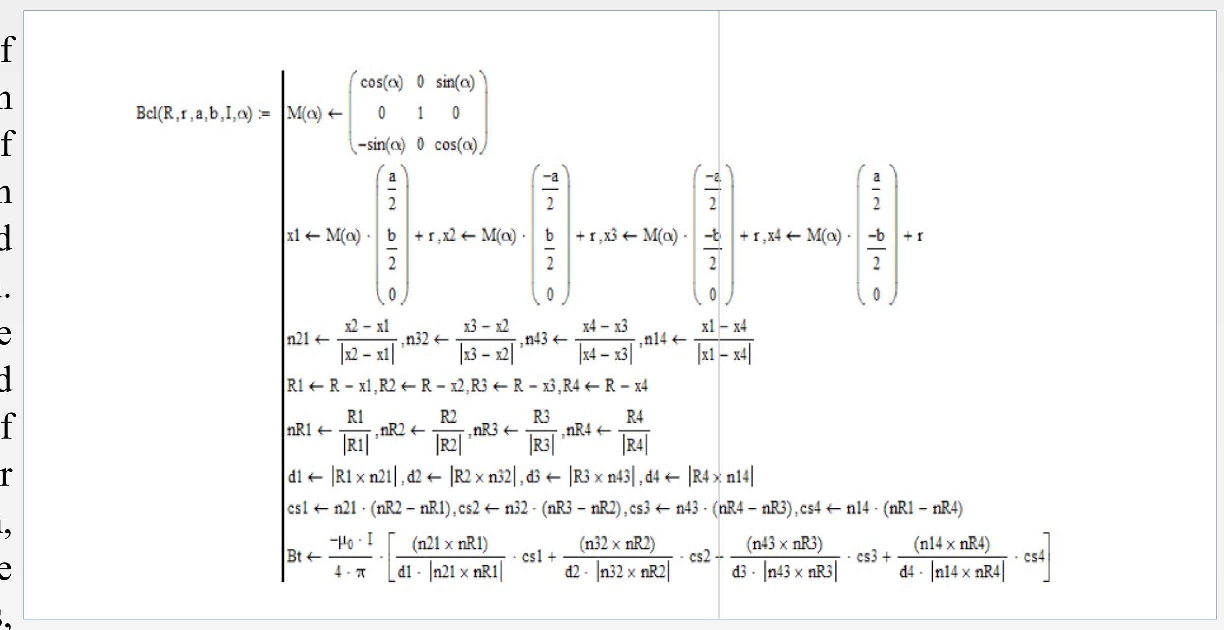

Figure 5: The microcode in the program Mathcad. This piece of code calculates the magnetic field from the current frame.

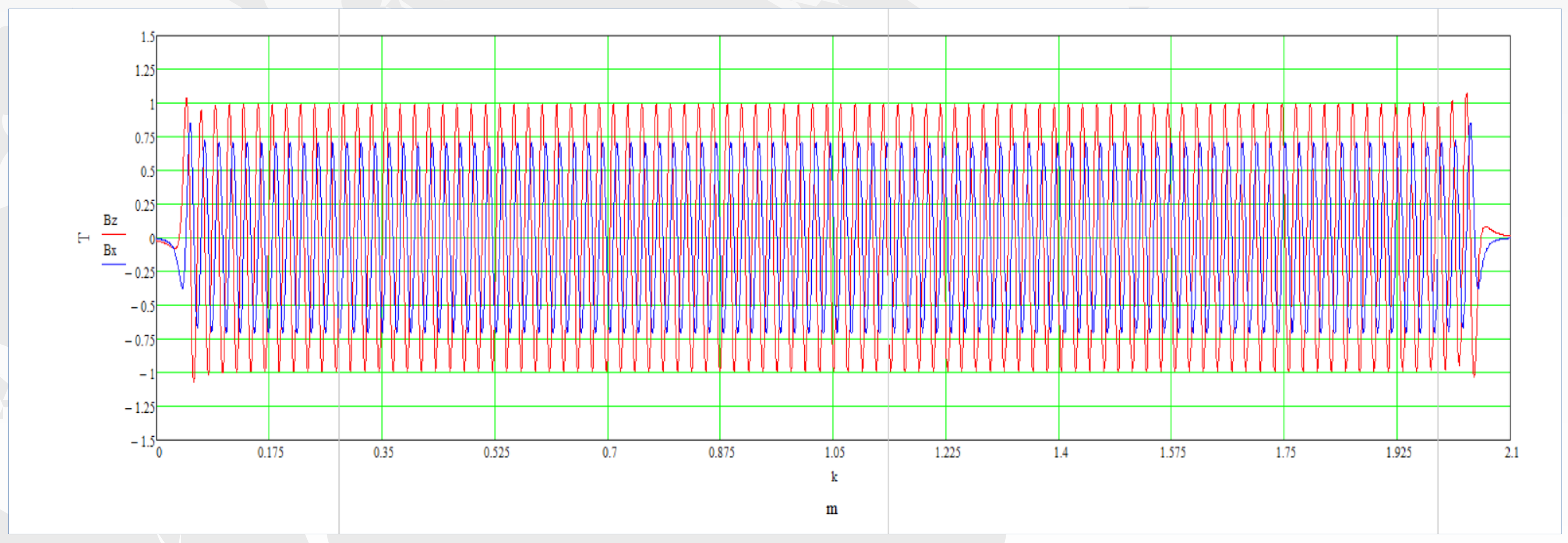

Figure 6: Simulated magnetic field of the undulator.

Spectral properties of synchrotron radiation.

The Spectra program version 10.02 was used to calculate the photon spectra. The supposed photon stream was viewed at a distance of 30 meters, at a solid angle of 10 microradians. The accelerator parameters are shown in figure 7. the Spectral properties are shown in the graphs in figure 8

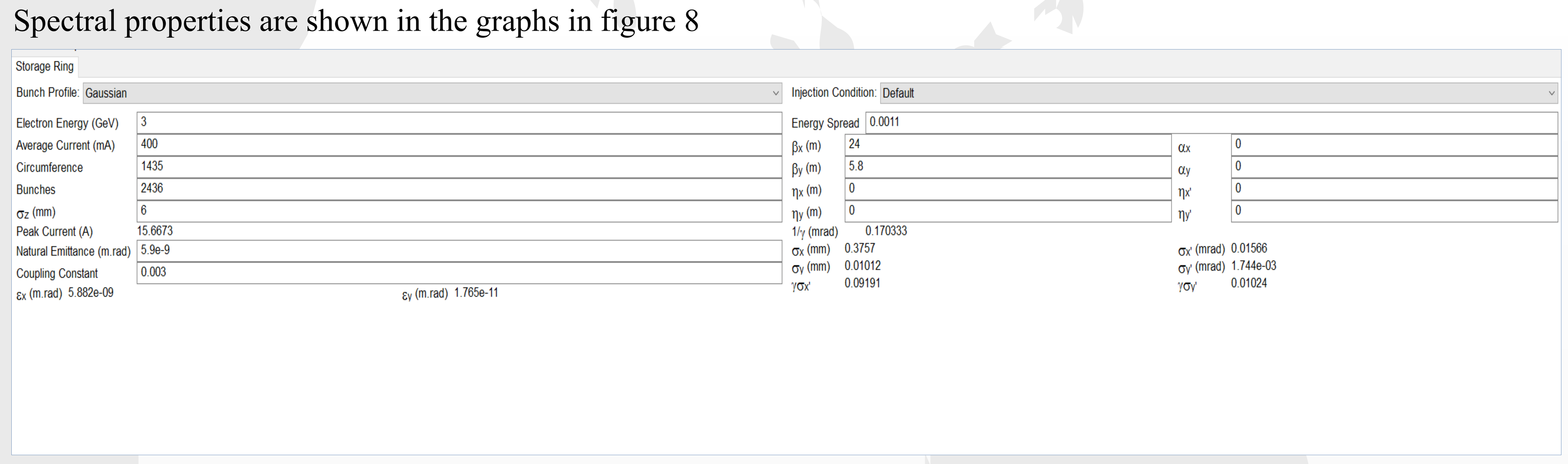

Figure 7: The accelerator parameters.

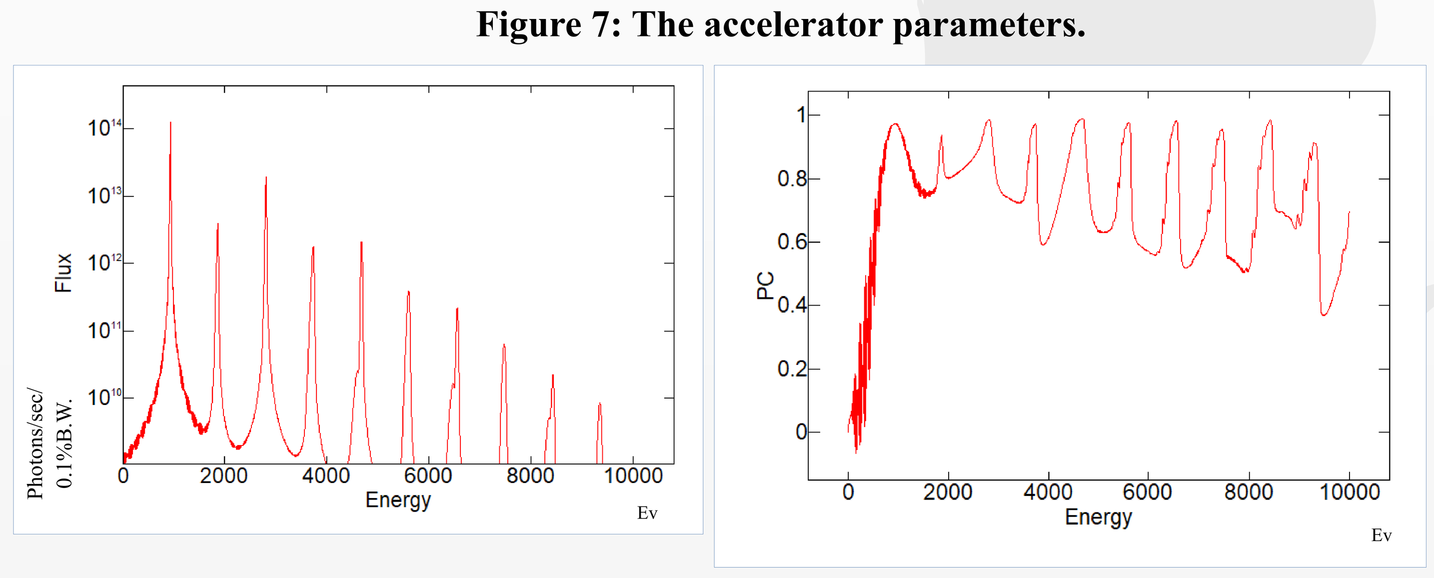

Figure 8. Spectrum at zero angle. **On the left, the photon flux per second into a solid angle of 10 microradians. On the right is the degree of circular polarization.**

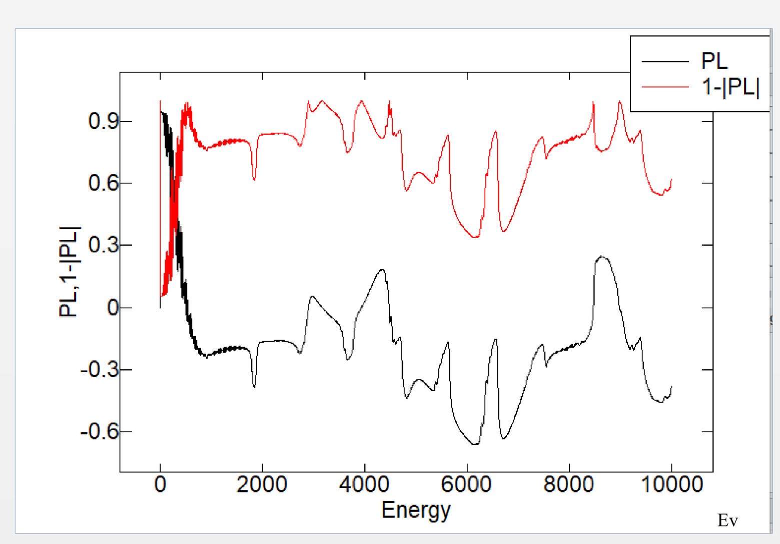

Figure 9 .The degree of linearly polarized photons.

CONCLUSIONS

The prototype of the spiral undulator was fabricated and measured. A scheme was proposed for the manufacture of an undulator with variable polarization of photons up to several kilohertz. Spectra of a possible elliptical undulator based on modeling and calculation in the Spectra program were also demonstrated.