7 TESLA 17-POLE SUPERCONDUCTING WIGGLER FOR BESSY-II

S.V. Khrushchev, M.V. Kuzin, N.A. Mezentsev, E.G. Miginsky, V.V. Repkov, V.M. Tsukanov, V.A. Shkaruba
Budker Institute of Nuclear Physics, SB RAS;
Lavrentyev ave. 11, 630090, Novosibirsk, Russia

7 Tesla 17-pole superconducting wiggler with a 19 mm magnetic gap and 148 mm in period have been fabricated in the Budker INP for the first time in the world. The maximum magnetic field, which can be generated on the central 13 poles, is 7.45 Tesla. To minimize magnetic gap the cold vacuum chamber with liquid helium temperature have been used. There is a 20 K copper liner inside the vacuum chamber to prevent it of heating by the electron beam. The inside cross section of the copper liner is 13·109.9 mm. The irradiation power is 60 kW for the electron beam current of 0.5 A and 1.9 GeV energy. The wiggler tests with the beam on the BESSY-II storage ring had been performed on March 2003. The main features of the wiggler design and the tests results are presented in this paper.

PACS: 29.17.+w,85.25.Ly

1. INTRODUCTION

The wiggler has been designed and fabricated in the Budker INP for the BESSY-II storage ring for generation of powerful X-ray radiation in the photon energy range up to 100 keV for materials science. Main parameters of the wiggler are presented in Table.

Number of poles main additional	 13 4
Vertical aperture, mm	13
Pole gap, mm	19
Main pole length (period), mm	74(148)
Nominal magnetic field, Tesla Maximum magnetic field, Tesla	7 7.45
Coil material	NbTi
Electron energy, GeV	1.9
Beam current, A	0.5
Radiation power, kWatt	60
Stored energy, kJ	460
Liquid helium consumption, l/hour	0.3 –0.65

2. MAGNETIC SYSTEM

The wiggler has 13 main poles and 4 additional end poles. Vertical aperture of the wiggler for the beam is 13 mm, and magnetic gap is 19 mm. The vacuum chamber inside the wiggler is an internal part of a liquid helium vessel and has a temperature of 4.2ºK. A copper liner is inserted into the vacuum chamber to prevent it heating by an electron beam. The vertical gap between the vacuum chamber and the liner is 1 mm. Thin stainless steel spacers with a low heat conductivity are used to provide the required gap between the liner and the vacuum chamber. The liner has thermal contact to the screen 20 K cooled by two cryocoolers.

Material of the coils is NbTi round wire. The period of 148 mm has been chosen to achieve maximal intensity radiation on photon energy ~14 keV at the limited length of the storage ring straight section. Maximal magnetic field obtained on 13 main poles is 7.45 Tesla. The working field is 7 Tesla. Coils of the central poles and ¾ poles have two sections. The photo of the central pole is given in Fig. 1. The points of load lines of internal and external sections describing a condition of a superconducting wire in the coil (at 7 Tesla in median plane) relative critical curve for a short sample of superconducting wire is given in Fig. 2.

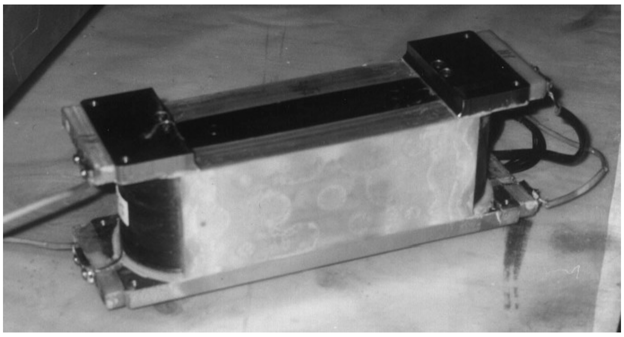

Fig. 1. The coil of the wiggler

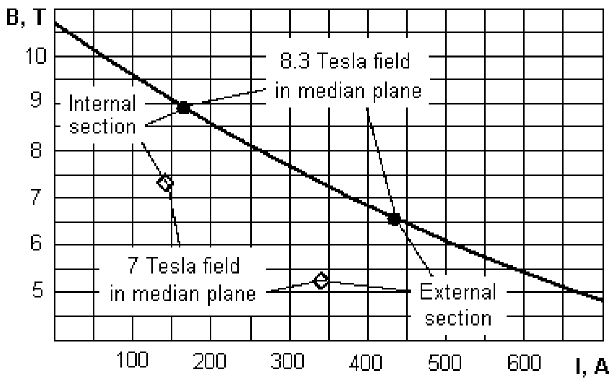

Fig. 2. The points of load lines describing a condition of a superconducting wire in the coil relative critical curve for a short sample of used wire

Two power supplies are used to feed the wiggler magnetic system. The currents on 7 Tesla magnetic field for first and second power supplies are equal to 145 A and 197 A correspondingly. The first current feeds internal sections of central coils, internal sections of ¾ coils and whole ¼ coils. The second current feeds external sections of ¾ coils. The sum of two currents feeds external sections of central coils. Such circuit gives an optimum current - field ratio on windings of the central poles, and keeps first field integral close to zero for any field level.

Special bandaging system is used to prevent winding wire motion under ponderomotive forces action. The bandaging system consists of two pair stainless steel thick plates, stretched together by eight bronze studs. The drawing of wiggler magnetic system is given in Fig. 3.

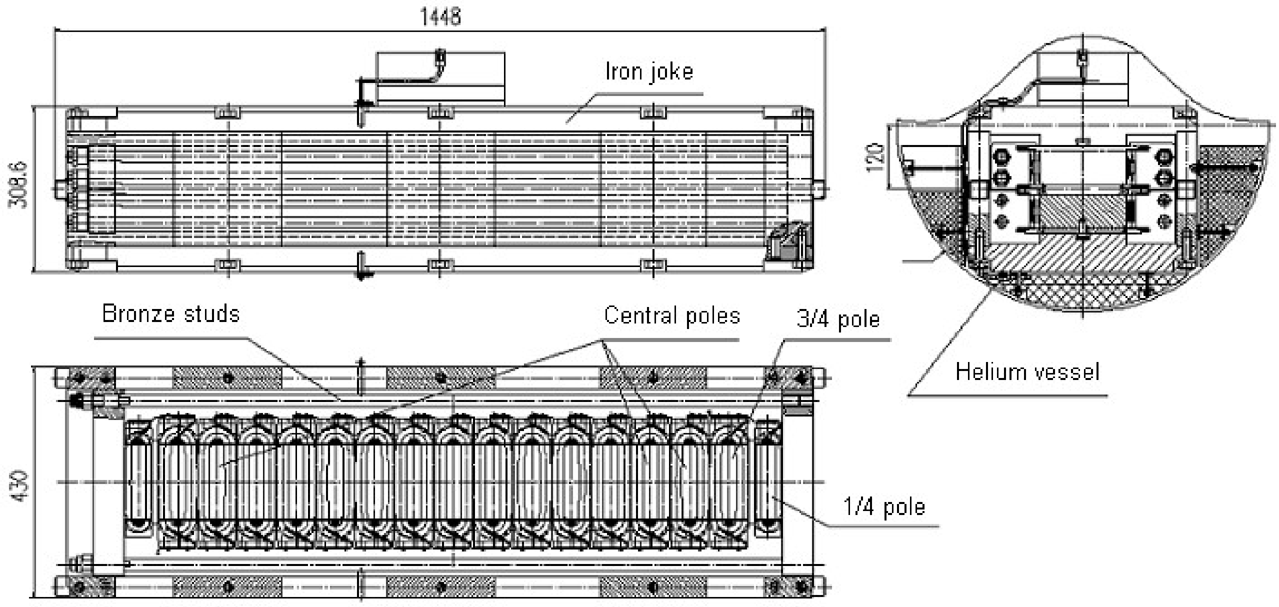

Fig. 3. The wiggler magnet system

3. MAGNETIC MEASUREMENTS

A special measuring system was made for magnetic field mapping. Complexity of this system is caused by application of the cold vacuum chamber and 20ºK liner in the wiggler and as consequence - impossibility to work on open air. The measuring system consists of a frame with two motions (one on each side of wiggler), directing tube (antechamber) with the Hall probe inside and two bellows. The frame is motionlessly fixed on the wiggler. Directing tube passes inside the 20ºK liner. Between this tube and the liner is vacuum to reduce heat inleak. During scanning of the tube inside the liner there is a possibility to synchronize motions of the tube ends. The vertical moving of directing tube is made manually. The ends of a tube are hermetically connected to the ends of the cold vacuum chamber through bellows. Thus the vacuum volume limited to the cold vacuum chamber, directing tube and two bellows is formed. Inside a tube there is a Hall probe, which is actuated by a horizontal drive of motions through a kevlar fiber.

Stretched wire method for field integrals measurements was used. To realize this the Hall probe was removed from the tube, and stretched wire was passed.

Transverse magnetic field distribution of one of central poles is given in Fig. 4. Parabola with factor 50 T/m^2 with X^2 is represented in the same figure. Thus on the central pole the magnetic field sextupole components does not exceed 100 T/m^2.

Longitudinal magnetic field distribution on a level 7 Tesla as well as angle orbit deviation and orbit distortion along the wiggler is shown in Fig.5.

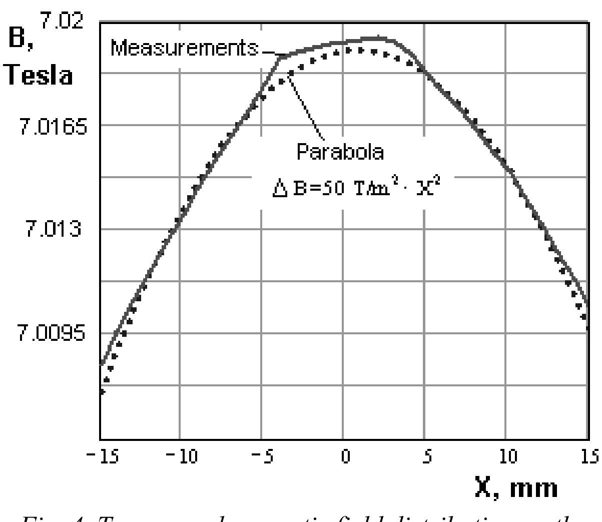

Fig. 4. Transversal magnetic field distribution on the central pole. (Solid curve- measurements, dot curve- parabola with factor 50 T/m^2 with X^2)

Residual fields in wiggler do not exceed 7·10^{-3} Tesla and 4·10^{-3} Tesla after slow down the field from maximum level, and after quench, respectively. The

PROBLEMS OF ATOMIC SIENCE AND TECHNOLOGY. 2004. № 1.
Series: Nuclear Physics Investigations (42), p.80-82.

ratio of the currents of first and second power supplies requested for zero first field integrals at any field level were obtained with the stretched wire method (Fig.6).

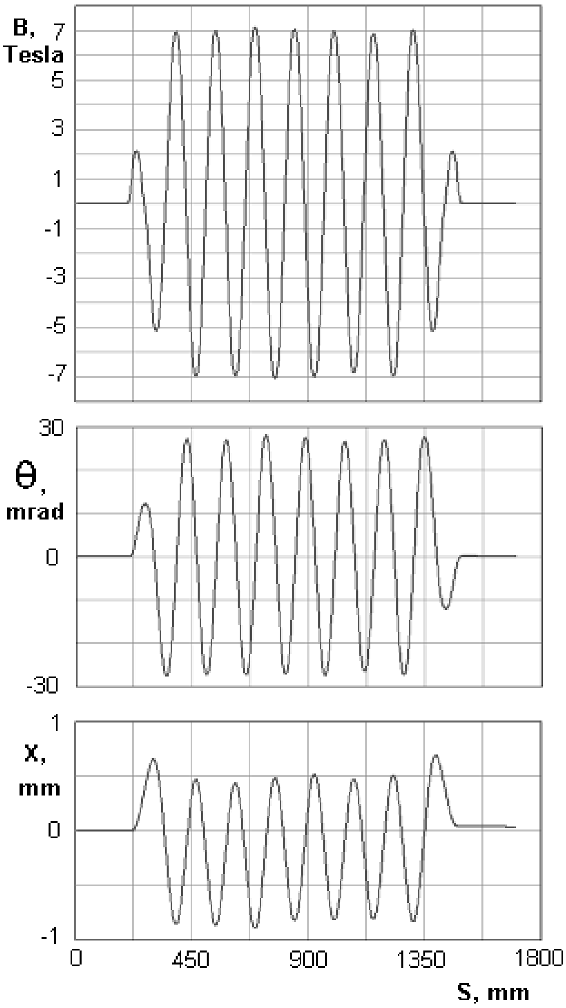

Fig.5. Longitudinal magnetic field distribution. Longitudinal distribution of a corner between the electron speed direction, and the wiggler longitudinal axis. The cross coordinate of the electron flying through the wiggler, depending on longitudinal coordinate

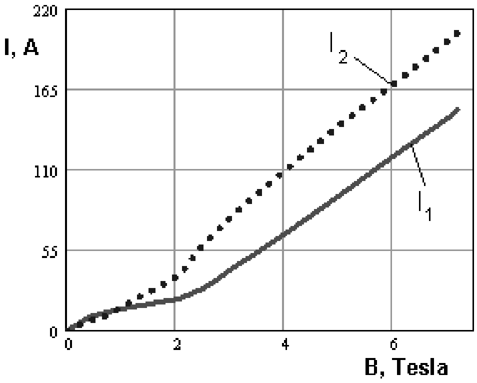

Fig.6. Currents in the windings, appropriate to zero first integral, depending on a magnetic field on the basic poles

4. CONCLUSION

Superconducting 7 Tesla multipole wiggler with 17 poles was designed, fabricated, successfully tested and installed on the BESSY-II ring with parameters as requested. It was demonstrated good agreement between calculated and measured magnetic field properties.

REFERENCES

1. D. Berger, M. Fedurin, N. Mezentsev, S. Mhaskar, F. Schaefers, M. Scheer, V. Shkaruba, E. Weihreter. *A superconducting 7 T multipole wiggler for the BESSY II Ring., PAC.01,* Chicago, 2001.
2. D. Berger, N. Mezentsev, V. Shkaruba, E. Weihreter. A superconducting 7T multipole wiggler for BESSY II: main challenges and first field measurements // *Proceedings of EPAC 2002, Paris, France.*
3. D. Berger, V. Duerr, H. Krauser, S. Reul, M. Rose, E. Weihreter. Mechanical and thermal design of vacuum chambers for a 7 T multipole wiggler for BESSY II. // *Proceedings of EPAC 2002, Paris, France.*

СВЕРХПРОВОДЯЩИЙ СЕМНАДЦАТИПОЛЮСНЫЙ 7 Тл ВИГГЛЕР ДЛЯ BESSY-II

С.В. Хрущёв, М.В. Кузин, Н.А. Мезенцев, Е.Г. Мигинская, В.В. Репков, В.М. Цуканов, В.А. Шкаруба

В Институте ядерной физики им. Г.И. Будкера СО РАН впервые в мире создан сверхпроводящий 17-полюсный вигглер с периодом 148 мм, межполюсным зазором 19 мм и номинальным полем 7 Тл. При этом максимально достигнутое поле на 13-ти основных полюсах составляет 7.45 Тл. С целью уменьшения межполюсного зазора применена вакуумная камера, имеющая температуру жидкого гелия. Чтобы предотвратить нагрев пучком вакуумной камеры, внутри неё помещен медный лайнер, имеющий температуру 20 К. Размеры поперечного сечения внутренней части медного лайнера составляют 13x109.9 мм. Мощность излучения из вигглера при токе пучка 0.5 А и энергии 1.9 ГэВ составляет 60 кВт. Испытания вигглера с пучком на накопительном кольце BESSY-II в Берлине были произведены в марте 2003 г.

НАДПРОВІДНИЙ СІМНАДЦЯТИПОЛЮСНИЙ 7 Тл ВИГГЛЕР ДЛЯ BESSY-II

С.В. Хрущов, М.В. Кузін, Н.А. Мезенцев, Є.Г. Мігінська, В.В. Репков, В.М. Цуканов, В.А. Шкаруба

В Інституті ядерної фізики ім. Г.І. Будкера СВ РАН вперше у світі створений надпровідний 17-полюсний вигглер з періодом 148 мм, міжполюсним зазором 19 мм і номінальним полем 7 Тл. При цьому максимально досягнуте поле на 13-ти основних полюсах складає 7.45 Тл. З метою зменшення міжполюсного зазору застосована вакуумна камера, що має температуру рідкого гелію. Щоб запобігти нагрівання пучком вакуумної камери, усередині неї розміщено мідний лайнер, що має температуру 20 К. Розміри поперечного переріза внутрішньої частини мідного лайнера складають 13x109.9 мм. Потужність випромінювання з

вигглера при струмі пучка 0.5 А и енергії 1.9 ГеВ складає 60 кВт. Іспиту вигглера з пучком на накопичувальному кільці BESSY-II у Берліні були зроблені в березні 2003 р.

PROBLEMS OF ATOMIC SIENCE AND TECHNOLOGY. 2004. № 1.
Series: Nuclear Physics Investigations (42), p.80-82.