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DESIGN, MANUFACTURING AND TEST OF A S.C. WIGGLER FACILITY FOR "ADONE" IN FRASCATI

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Abstract

A synchrotron light source to generate hard X ray photons has been designed for the storage ring Adone at Laboratori Nazionali INFN, Frascati. The facility consists of a superconducting wiggler, built by Ansaldo Componenti, and two warm magnets, home made, needed to compensate the field in such a way that the first integral of the vertical field component should vanish. The one pole superconducting wiggler has a measured magnetic field peak of 6.025 ± 0.003 Tesla. The two compensator magnets generate a maximum field of 0.85 Tesla. A 1430 S Koch liquefier/refrigerator on line with the s.c. magnet keeps it cooled at 4.6°K.

Introduction

The aim of this facility is to shift the "universal" spectral curve of the synchrotron radiation from the Adone bending magnets towards higher energy photons. At the energy of 1.5 GeV (Bbending = 1 Tesla) and for a circulating beam of 100 mA, the emitted Photons/s/mrad in 0.1% band-width, at 1.5 KeV critical energy, are about $2.4*10^{12}$ (fig.1).

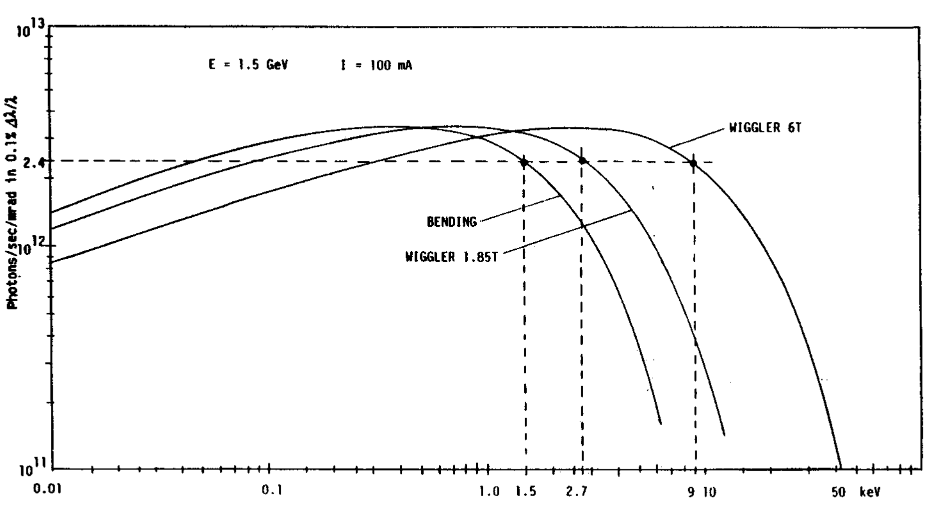

Fig. 1

The same flux can be obtained with photons of ≈ 9 KeV critical energy generating on the beam trajectory a 6 Tesla magnetic field. To reach the goal of having a very simple light source structure and a compensated magnetic field integral, a peculiar magnetic field pattern along the beam trajectory has been adopted (fig. 2). The chosen field profile and symmetry, drive the electrons on a single orbit bump in the horizontal plane. A single " wiggle " creates a single bright spot in the horizontal (and vertical) phase space. A brief description of the whole facility is given here below.

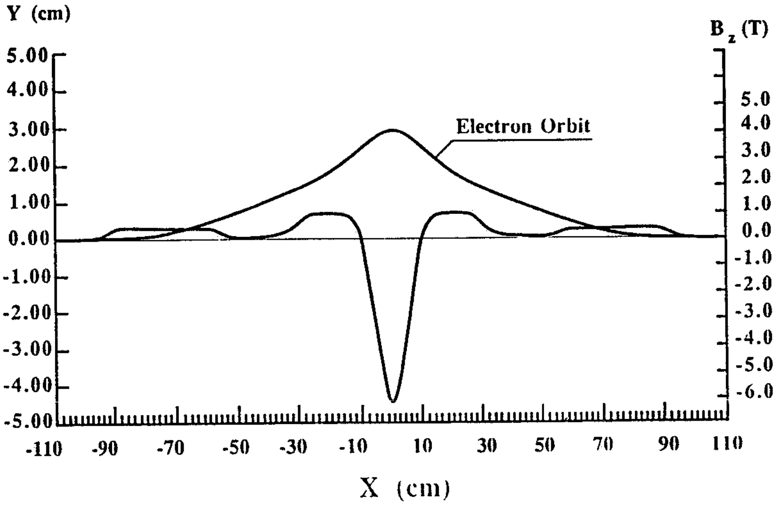

Fig. 2

Superconducting cable

To obtain the magnetic field profile shown in fig. 2, about 777000 A-turns are needed for each coil. A superconducting cable having 2 * 1 mm^2 rectangular cross section, the Vacryflux 5001 manufactured by Vacuumschmelze, has been chosen. The cable has 312 filaments (diameter 45 μm) of NbTi embedded in a high conductivity copper matrix (Cu/NbTi ratio = 2.71), it is electrically insulated with E-glass fibre braid and epoxy impregnated. The twist pitch is 45 mm and the critical current is 450 A at 4.6°K and B=7 Tesla.

Superconducting coil

The race-track superconducting coil has a cross section of 79 * 83 mm^2, it is made up of 67 layers, 39 turns each. On the coil heads, the turns are thinned out introducing an insulating separator (maximum thickness 20 mm). The electrical characteristics of the coil are: R = 26.78 Ω, L = 1.22 H (1 kHz).

Power supply

The power supply of the superconducting wiggler is a 10 V, 1000 A, SCR's regulated. It has a 0.1 % current set point and a remote panel for commands and controls.

The power supply is made up of a very high precision DCCT that warrants the stability and the ripple to be better than 0.01 %. An external stainless steel resistance, 3 Ω, 120 kJ, 20 - 120 °C, is in parallel between the output bars, allowing the discharge of the magnetic energy stored by the magnet during the quench.

Mechanical design

The mechanical structure of the s.c. magnet is rather unusual due to the need for a large quasi-elliptic aperture (19x3.2 cm.) for the beam to stay clear in Adone. In addition, the cryostat has a warm bore, which means that the actual pole gap must accommodate also the bore vacuum insulation and this increases the transverse dimension of the magnetic yoke. Fig.3 shows the mechanical lay-out. The large race track coils are supported by the magnet yoke only over a short length of the long side, and not at all at the curved heads. No reinforcing rings are allowed in order to avoid complicating the construction and enlarging the helium vessel transverse cross section.

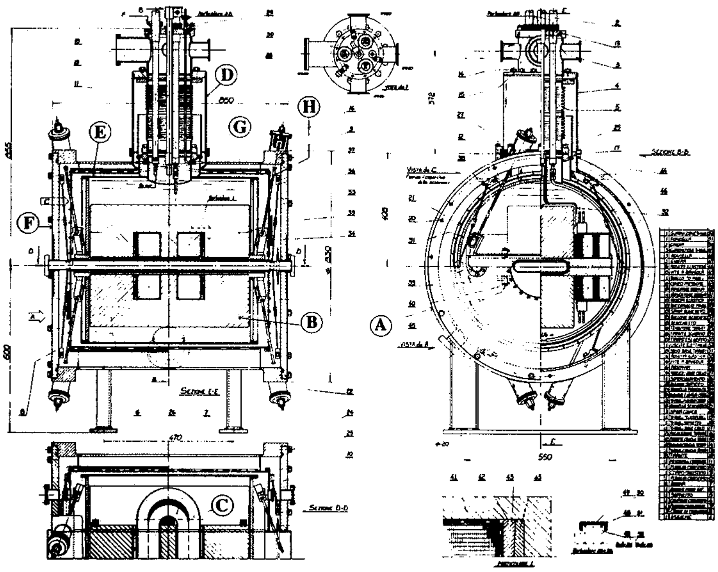

Fig. 3

Cryostat design

The two s.c. coils, the two yokes and the central plate are cooled by boiling helium at 4.6 °K. The main cryostat components are : the external vessel, the helium vessel, the radiation screen, the service turret. The cylindrical external vessel is made in austenitic stainless-steel AISI 304L, its rupture pressure is 40 atm. The helium vessel is made in stainless-steel AISI 316L and consists of a cylindrical shell closed by flat end covers TIG welded; the leak rate is 10^{-12} Torr l/sec. The radiation screen is made of OFHC copper, it incorporates a cooling circuit in which the boil-off vapor from the helium bath flows. The end plates of the screen are cooled by conduction; the screen is wrapped with 50 layers of aluminized mylar super-insulation, crinkled. After outgassing, the initial vacuum of 10^{-4} Torr is improved by cryo-pumping up to 10^{-6} Torr, maintained by a 100 l/h diffusion pump.

The magnet, which has a mass of 300 Kg, is suspended at its quarter points by 8 tension rods made in titanium alloy to reduce the heat leak at 0.1 W. The service turret is located on the neck of the cryostat to allow the current leads transporting the current to the s.c. coils. On the top of the turret there is a flange with three bayonet attacks for the helium transfer lines. The heat leaks calculated are 5.9 W for I=400 A. The measured ones are 4.6 W at I=317 A.

The refrigerator

A system consisting of a 1430S KPS liquefier/refrigerator, having a liquefaction rate of 22 l/h and a refrigeration capacity up to 60 W, has been installed in the laboratory. The cold box is connected with a 1000 l stocking dewar through a 1.4 m delivery tube. When installing the wiggler on Adone a smaller dedicated on line refrigerator will be used. Two other transfer lines have been built for connecting the refrigerator to the wiggler cryostat.The cold box is driven by two reciprocating compressors. Fig.4 shows a schematic view of the whole system.

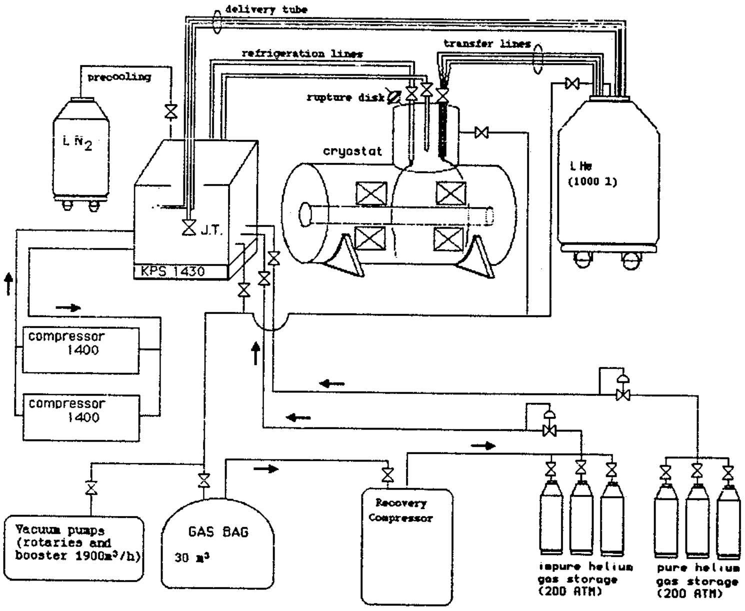

Fig. 4

Compensator magnets design

Mechanical constrains have enforced a compensator length of 0.33 m each and a magnetic field of 0.57 T. In order to avoid quadrupolar gradients, an H configuration has been chosen, with a pole width/gap = 4. The gap is 50 mm and a maximum field of 0.85 Tesla can be reached. The magnetic field profile has been studied by means of the bidimensional code Magnet. Two 1 cm width, stepped lateral shims have been added to optimize the useful zone. The magnetic field measurements fit the code previsions within 1%. If the sextupole field term introduced by the wiggler has to be corrected, the compensator pole surfaces can be machined so that a sextupole term having the opposite slope is obtained. Fig. 5 shows the mechanical lay-out of the compensator magnets realized using Armco iron. Two power supplies, 0÷22 V 0÷1000 A, have been designed and constructed.

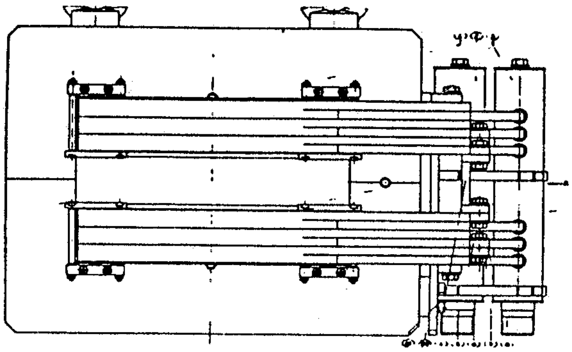

Fig. 5

S.C. wiggler cool down

The cryostat (capacity: 70 liters of liquid helium) has been filled at Ansaldo works where preliminary tests have been carried out, first with liquid N2 and then with He using dewars. During the first cool down, a safe cooling speed was adopted, of the order of 2 K/hour. In the range from 300 to 80 K the maximum Δt across the magnet has been 50 K, measured through CLTS sensors. With the liquid helium at its maximum level and after a thermalisation period, an average temperature of 50- 60 K was measured at the radiation shields. Fig. 6 shows the magnet training. The quenches were due to mechanical settlement of the coil and yoke under electromagnetic forces and not to conductor current limits.

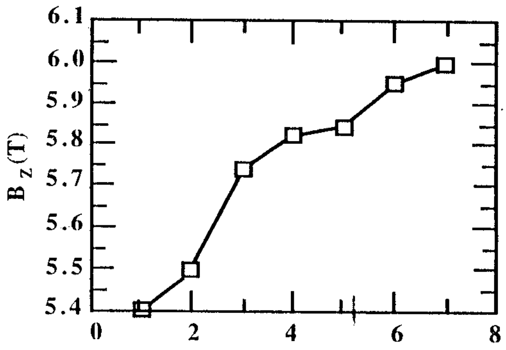

Fig. 6

S.C. magnet field profiles

The measurements have been made using an integrating magnetometer: a manually rotated small coil connected to an integrator made with very highly stabilized integrating circuits. The coil has a diameter of 5 mm and is 5 mm high. It has a measurement accuracy of 0.05 % of full scale over the three ranges 200 mT, 2 T, 20 T. The flip coil was held in position and moved in steps along the wiggler symmetry axes using a mechanical actuator with an accuracy of better than 1/10 mm. Field profiles have been measured at 5.0, 5.75, 6.0 Tesla. Fig. 7 shows the results and Fig. 8 shows the comparison with the output of the tridimensional computer codes Tosca and Magnus. The experimental data are in good agreement with the code previsions.

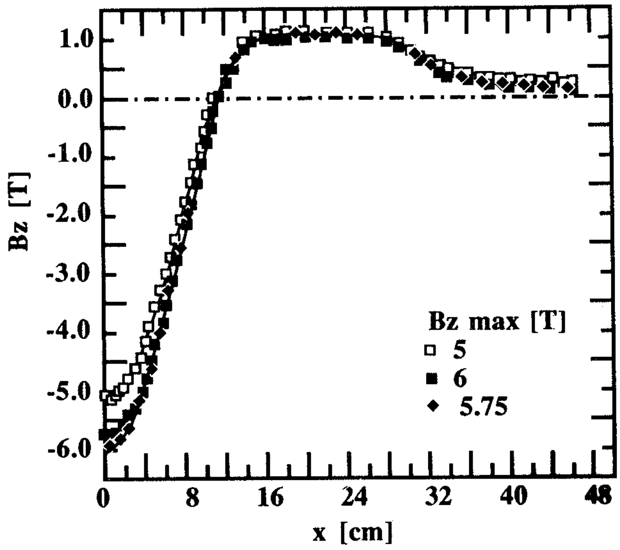

Fig. 7

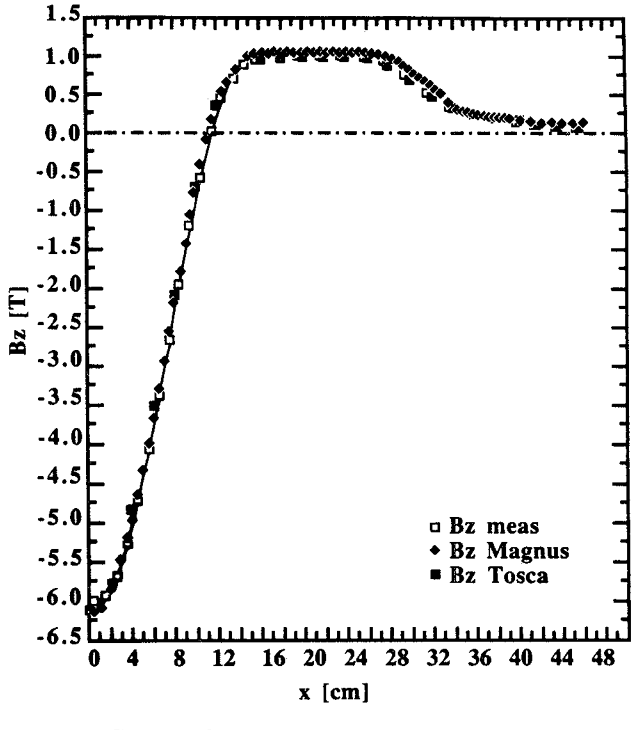

Fig. 8

Conclusions

The field profiles obtained (exceeding 6 Tesla with high stability for the s.c. wiggler and 0.85 Tesla for the compensator magnets), are proof of the magnet's reliability and confirm the design goal.