BEPCⅡ Positron Source

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Abstract BEPCⅡ— an upgrade project of the Beijing Electron Positron Collider (BEPC) is a factory type of e^+e^- collider. The fundamental requirements for its injector linac are the beam energy of 1.89GeV for on-energy injection and a 40mA positron beam current at the linac end with a low beam emittance of 1.6μm and a low energy spread of ±0.5% so as to guarantee a higher injection rate (⩾50mA/min) to the storage ring. Since the positron flux is proportional to the primary electron beam power on the target, we will increase the electron gun current from 4A to 10A by using a new electron gun system and increase the primary electron energy from 120MeV to 240MeV. The positron source itself is an extremely important system for producing more positrons, including a positron converter target chamber, a 12kA flux modulator, the 7m focusing module with DC power supplies and the support. The new positron production linac from the electron gun to the positron source has been installed into the tunnel. In what follows, we will emphasize the positron source design, manufacture and tests.

Key words positron source, flux concentrator, converter target, pulse power supply

1 Introduction

BEPCⅡ is the second phased construction of BEPC, working in the Tau-Charm energy region (2—5GeV). The design peak luminosity of $1\times10^{33}\text{cm}^{-2}\cdot\text{s}^{-1}$ at 1.89GeV is two orders of magnitude higher than the present BEPC. To keep a higher average luminosity, on-energy injection with a high injection rate of ⩾50mA/min for e^+ beam is necessary, which is ten times the present value. The measures[1] we're going to take include: 1) increase the repetition rate from 12.5Hz to 50Hz; 2) increase the bombarding electron energy from 140MeV to 240MeV; 3) increase bombarding electron current from 2.5A to 6A and 4) manufacture a new positron source to increase the positron yield at the linac end from 1.4% to 2.7% $e^+/(e^-\times\text{GeV})$. Table 1 shows the main parameters of the BEPCⅡ positron source.

Table 1. The main parameters of the BEPCⅡ e^+ source.

positron energy	1.89GeV
positron current	37mA
energy spread	⩽±0.5%
beam emittance	1.6μm
positron source system	
target (W)	8mm
e^- energy on target	240MeV
e^- current on target	6A
peak field of FLUX	4.5T
DC field of solenoid	0.5T
e^+ yield at solenoid end	$0.043e^+/(e^-\cdot\text{GeV})$
e^+ yield at the linac end	$0.026e^+/(e^-\cdot\text{GeV})$

2 Positron converter assembly

The BEPCⅡ positron source[2] is a conventional source. Electrons are accelerated to 240MeV in the linac, and focused to a 3mm to 5mm diameter spot

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on a tungsten target. The target itself is a 10mm diameter, 8mm thick disk. The disk is copper plated, cast in sterling silver with its cooling tubes, and post-machined to size. Simulation shows the mechanical and thermal tensile strengths are not a problem for about 500W electron beam power. The target arm assembly is suspended and supported in the vacuum chamber by the target housing mounted outside the chamber. A bellows is used to feed the target into the vacuum chamber and provide a flexible pivot. The actuation system is an eccentric axletree. With a stepping motor, it can easily move the target in and out of the beam line.

The pair-produced positrons out of target have divergent angles, a broad energy spectrum, and a much larger emittance than that of the initial electron beam; thus a matching device is first needed to transfer an "erect ellipse" transverse emittance of the positron beam to a "horizontal ellipse" acceptance of the downstream system. We use SLAC type matching device, a flux concentrator[3] (FLUX). It is a 12-turn, 10cm long copper coil with a cylindrical outside radius of 53mm and a conical inside radius growing from 3.5mm to 26mm. The 0.2mm gaps between the individual windings are manufactured by electric discharge machining out of one copper block. Excitation current and water-cooling is provided by a hollow rectangular copper conductor brazed to the outside

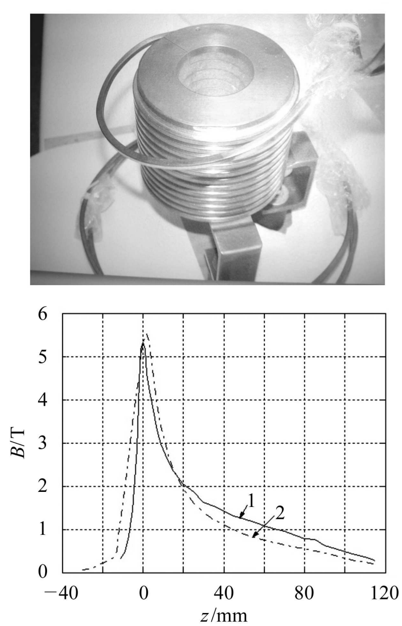

Fig. 1. Picture of the e^+ FLUX and its field profiles.

of the coil (also 12 turns). Fig. 1 shows the picture of the flux concentrator and its magnetic field profiles. The dotted line is the OPERA simulated result and the solid line is the measured result[4], both are well matched.

A high DC magnetic field of tapered field solenoid (TFS) is required at the target downstream face to capture the low energy positrons. POISSON computer code is used to optimize the flux return iron geometry and coil placement around the target chamber. At a maximum current of 750A, the TFS generates a 12kG DC field at the target exit face. A pair of steering coils is considered to compensate the stray field. The vacuum chamber is contained within the TFS. It is a custom design to maintain structural rigidity, provide the maximum pumping speed to the target and flux concentrator area, accommodate the pole tip section of the TFS flux return iron, mate up to the existing RF structure section, and allow the target and flux concentrator to be removed independently. The downstream vacuum flange of the chamber is quick-disconnect flange. A custom aluminium seal between the chamber flange and the mating flange of the accelerator structure downstream is used. A single convolution bellows between the chamber and the flange provides enough compliance to take up any slight angular misalignments of the two mating flanges while still being rigid enough to support the flange without vertical restraint. Fig. 2 is the picture of the BEPCⅡ positron converter assembly.

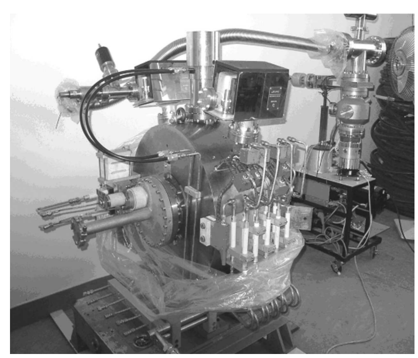

Fig. 2. Picture of the e^+ converter assembly.

3 Positron flux modulator

The flux modulator for the BEPCⅡ positron source provides 12kA in a 5μs sinusoidal half wave current at 50pps to produce an adiabatic magnetic field profile with the peak of 4.5T at the flux entrance face. The modulator uses two CX1536 thyratrons in a switching network, and provides reliable operation with acceptable thyratron lifetime.

There are two such basic modulators, one is the SLAC flux modulator[5] and the other one is the PLS design for the injection kicker[6]. Their basic circuits are the same, an RLC resonant circuit. The SLAC design uses 8 forward CX1622 glass thyratrons to generate pulse current and uses 2 inverse CX1622s and water cooled resistor to minimize inverse voltage and uses resonant charging DC power supply. The PLS design only uses 2 CX1536 thyratrons to generate pulse current and uses RC auxiliary circuit and energy dump circuit to minimize inverse voltage. The BEPCⅡ flux modulator uses PLS design because it is much easier to synchronize trigger time. Also, CCDS charging power supply is more compact and more efficient than the resonant charging DC power supply.

A schematic circuit diagram of the BEPCⅡflux concentrator modulator is shown in Fig. 3. The charge assembly of the modulator mainly consist of a CCDS power supply, a charging resistor, the charging diodes, and main capacitors. The discharge assembly is two thyratrons, inverse energy dump assemblies, and transient suppression assemblies. The reduction of system inverse voltage is a design issue to make a reliable operation and meet the pulse requirements. The peak inverse voltage, including spike must not exceed 10kV for the first 25μs after the anode pulse, because this can cause reverse conduction in the thyratron and therefore damage the tube. The other issue is the inductance reduction, because the flux concentrator modulator design requires a high current pulse

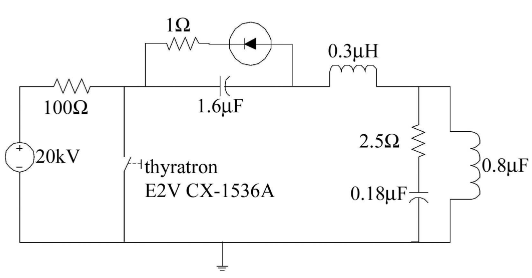

Fig. 3. Circuit diagram of the BEPCⅡ flux concentrator modulator.

into an inductive load. This is accomplished by building wide current paths while minimizing the current loops. The modulator has 15m long multi cables, and they are connected in parallel at the load. Creating 20 parallel paths reduces the system inductance, thus increasing the system reliability.

The new modulator was installed in the klystron gallery in the summer shutdown of 2003, and first operated for BEPC matching solenoid at 6kA, 12.5pps. Since the new positron source installed in the tunnel at the October 2004, we've tested the modulator with the flux concentrator at 50pps, 12kA. Fig. 4 is the pulse current of flux concentrator, the pulse bottom width is about 8μs, and because of the mismatch between the impedance of the load and the pulse cables, reflections occur up and down the cables adding an oscillation on top of the load current. The saturable inductors in series with the thyratron can help minimize these oscillations by initially slowing the rate of rise of voltage across the load.

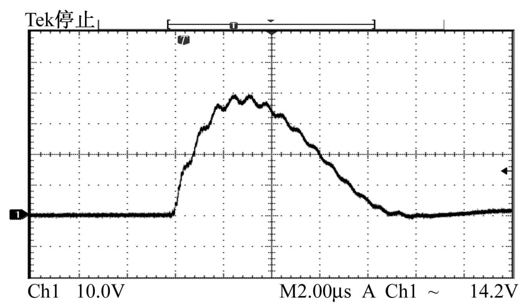

Fig. 4. Pulse current of flux concentrator.

4 Focusing module and support

The positrons out of target have larger divergent angles. And an intensive longitudinal magnetic field of 0.5T which provides a maximum transverse acceptance of $0.31\pi(\mathrm{MeV}/c)\cdot\mathrm{cm}$, is required to confine the positrons during capturing and accelerating. POISSON has been run to optimize the coil arrangements and the flux return iron geometry. At a DC driving current of about 400A, the seven 1 meter long focusing modules can provide 0.5T magnetic field with a drop of less than 5% in the gap between two modules. Between each module and RF structure, there is a pair of steering coils to guide the positron beam.

The positrons out of the focusing modules are about 100MeV, which makes good match into the downstream quadrupole focusing system.

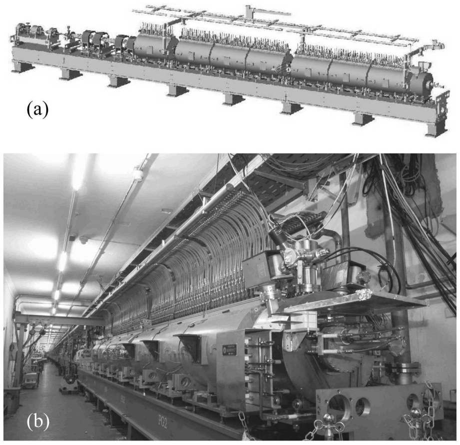

Fig. 5. (a) The positron source 3D model; (b) Picture of the positron source.

The hollow square conductor is used to wrap the pancakes with insulating tape, and then the coils are encased and epoxyed. The electrical connection is in series, and the cooling circuits connected in parallel. The epoxyed pancakes are assembled and aligned in the case which is fabricated from low carbon steel. The pancake's second epoxy is conducted to form the focusing module. Since the focusing modules are heavy, each of about 2 tons, the support structures[1)] are newly designed to replace the existing girders as shown in Fig. 5. The focusing modules are fastened to moveable platform supported on the rails oriented parallel to beam axis. A little lateral motion is possible for alignment. In order to install the modules on the RF structures, the output coupler is specially designed with a short flange and the cooling tube joints are moved to the input coupler end.

5 Interlocks

The whole positron source is comprised of several interlocks, many of which are attributed to the flux modulator and DC power supplies. Besides the personnel safety interlocks, there are also interlocks for equipment protection, including a water flow interlock for the water cooled resistors and power supplies, an over-current interlock that monitors the input current of the power supply, a temperature sensor for the water flow, a vacuum interlock for the power supply, and a crowbar interlock to protect the modulator from excessive charging current and charging voltage.

6 Conclusion

The new BEPCⅡ positron source has been designed and fabricated since 2002, and the whole system installed into the tunnel1 in five months from May 1st of 2004. Each system has been tested with satisfactory results. Now the BEPC linac is running for synchrotron radiation use up to the end of June in 2005. From then on, the positron linac commissioning has been conducted, and the first positron beam of higher than 40mA was obtained at the linac end on March 19, 2005. A positron current of higher than 60mA at the positron solenoid end was obtained. It confirms that the design, construction and installation of this new positron source are correct and successful.

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BEPCⅡ 正电子源

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摘要 BEPCⅡ 是一粒子工厂型的正负电子对撞机, 为北京正负电子对撞机(BEPC)的改造、升级工程. 它对直线注入器的基本要求是40mA, 1.89GeV的正电子束流, 发射度1.6μm, 能散度好于±0.5%, 保证储存环的注入速率≥50mA/min, 实现TOP OFF注入方式. 因为正电子流强与打靶电子束流功率成正比, 采用一把新的10A电子枪来提高打靶电流, 采用新加速结构和65MW速调管SLAC5045把目前140MeV的打靶能量提高到240MeV. 正电子源本身也是一非常关键、极其复杂的系统, 它包括正电子转换靶室、12kA"磁号"脉冲电源、7m长聚焦节、大功率直流电源和支架等. 目前, 正电子产生加速器, 从电子枪直到正电子源, 已经安装到了BEPC直线加速器隧道. 本文将着重介绍正电子源系统的设计、加工和测试.

关键词 正电子源 磁通压缩器 转换靶 脉冲电源

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