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A NEW ILC POSITRON SOURCE TARGET SYSTEM USING SLIDING CONTACT COOLING*

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Abstract

The R&D of the baseline positron source target for ILC is still ongoing after TDR due to the uncertainty of rotating vacuum seal and water cooling system of the fast spinning target wheel. Different institutes around the globe have proposed different approaches to tackle this issue. A spinning target wheel system with sliding contact cooling has been proposed by ANL. The proposed system eliminated the needs of rotating vacuum seal by using magnet bearings and vacuum compatible motor driven solid spinning wheel target. The energy deposited from positron production process is taken away via sliding cooling pads sliding against the spinning wheel.

INTRODUCTION

The ILC baseline positron source [1] is a helical undulator based positron source which produces 2×10^{10} positrons per bunch at the IP with the nominal ILC bunch structure and pulse repetition rate. It is designed with a 50% overhead and can deliver up to 3×10^{10} at injection into the 0.075 mrad transverse dynamic apertures of the damping ring. The main electron linac beam has an energy that varies between 100 and 250 GeV and passes through ~150m of helical undulator, with a 1.15 cm period and a K value of 0.92. At 150 GeV, the first harmonic cut-off of the photon drive beam is 10.1 MeV and the beam power is ~63 kW. Approximately 4.4 kW of this power is deposited in the target in ~1mm rms spot. A windowless moving target is required to handle the high beam power and heat deposition.

The ILC baseline positron production target [1] is a rotating titanium alloy wheel. The target wheels sit in a vacuum enclosure at 10^{-8} Torr (needed for NC RF operation), which requires vacuum seals for access to the vacuum chamber. The rotating shaft penetrates the enclosure using one vacuum pass-through. The R&D of target remains on-going. Even though the vacuum specification of the rotating vacuum seal has been demonstrated, its lifetime and reliability still requires further R&D. Many alternative target schemes have been discussed by collaborating researchers around the globe. The simplest one have been discussed is to use differential pumping to replace the rotating vacuum seal and keep the current configuration of water cooling from inside the target wheel. This scheme could eliminate the possible failure of the vacuum but still have the potential mechanical problem associated the water cooling channels inside the target wheel. To further address the ILC positron source target issue, DESY group proposed a radiation cooling scheme [2] and ANL group proposed a discrete target system [3].

The discrete target system adopted the concept of EM rail gun to eliminated the mechanical motion coupler of any kind between inside and outside of vacuum and thus eliminated the potential life time and reliability problem of the current ILC target system. But it needs a larger scale of changing to the current ILC positron source layouts which is not preferred.

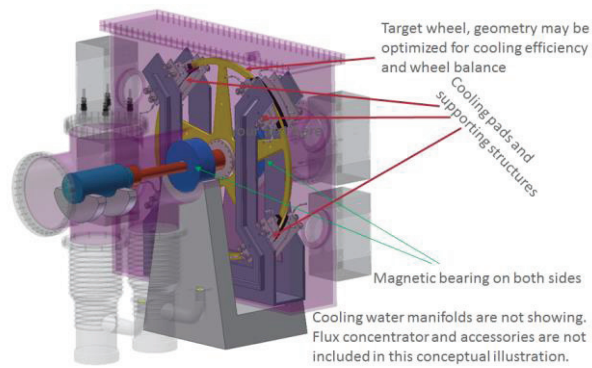

Figure 1: Conceptual illustration.

The original problem with the spinning wheel target is introduced as a result of water cooling from inside of the spinning target wheel. If we were not trying to cool the target from inside the spinning wheel, we won't need the rotational water union and thus eliminate the potential premature failure of the target system. The DESY group is working on the radiation cooling scheme. As a backup plan, we are looking into the sliding contact cooling scheme. The details of this sliding contact cooling scheme for ILC undulator based positron source are presented here in this paper.

GENERAL CONSIDERATIONS

As illustrated in Fig. 1, instead of cooling the target with water flow inside the target wheel, we use spring loaded cooling pads sliding against the target wheel and taking away the energy deposited in target resulting from positron production. Inside the cooling pads are cooling channels with cooling liquid flowing constantly. Since

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the cooling pads are stationary, the manifolds and vacuum feedthroughs can be easily implemented. This change eliminated the needs of water cooling channels inside the target wheel and feeding cooling water through the shaft and thus the rotation water union. One step forward, with a vacuum compatible motor, we enclosed the whole target system inside a vacuum chamber as illustrated in Fig. 1 and eliminated the needs of rotation vacuum seal altogether.

Vacuum Compatible Electrical Motor

One needs to remember that magnetic motor does not require lubrication itself as long as bearings are lubricated correctly. We consider a motor drive that is oil free and maintenance free.

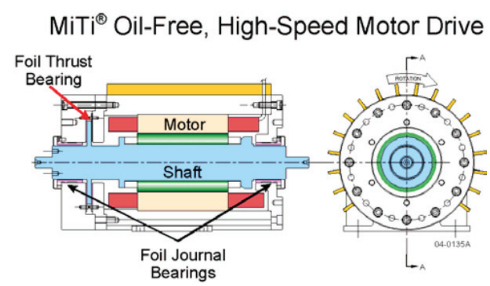

Figure 2: A high speed high power vacuum compatible motor.

By doing a web search, we found this, as illustrated in Fig 2, MiTi®'s 32 kW, 60,000 rpm Oil-Free, High-Speed Motor. So high speed, high power and vacuum compatible motors are commercial available.

Since the radiation level at the target area are very high and thus the radiation hardness of the motor should be one of the criteria for selecting the motor or design the motor. Vacuum compatible and radiation hard motors have been used in neutron chopper at some neutron facility. Even though the motor being used doesn't meet the requirements to drive the ILC positron source target, the technologies are there for us to design and build one.

Magnetic Bearing

To make the system vacuum compatible and provide strong support to the spinning target wheel, as illustrated in Fig. 3, magnetic bearing [4] will be used to provide support to the shaft from both side of the target wheel. Magnetic bearings use magnetic field to support moving parts without any physical contact and thus there will be no mechanical wear. By supporting the shaft from both side of spinning target wheel with magnetic bearing, the target wheel will be more stable than the original design where the shaft was only supported from one side of the target wheel.

Cooling Pads

The cooling pads will be in contact with target wheel to take the energy deposited by the positron production process. Meanwhile, as the cooling pads are sliding on the surface of target, the friction will generate extra heat. So the total cooling capacity of cooling pads have to be big enough to take away both the beam deposited energy and the heat generated by the frictions.

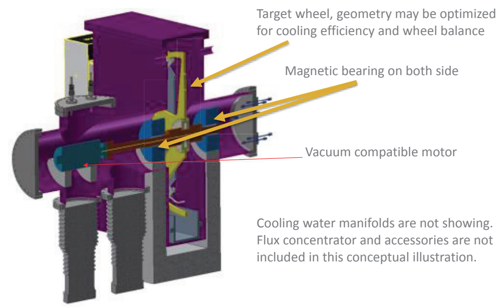

Figure 3: Cross section view.

For the ILC TDR beam parameters, the beam deposited power is about 7.5kW. Added in the 8kW of eddy current power loss [5] with duty factor of 0.05 (5Hz with inflated pulse length of 10ms), 0.4kW. Assuming 300cm^2 of total contact area, friction of 0.1 and contact pressure of 1N/cm^2, then the friction heating will be 3kW. Adding these number together, the total power needs to be removed from the system is about 11kW. With ~100% overhead, to remove about 20kW of heating power from the target, the temperature on the surface of target wheel will be about 38 degrees above ambient temperature.

The friction coefficient can be further relaxed, if we allow the working temperature to increase even higher. So friction heating is not a big deal as long as the motor we choose is capable of driving the wheel with friction load and the contacting surface can last.

On the other hand, the friction coefficient can be lowered by using vacuum compatible lubricant, WS2. WS2 is a magic material, which has following properties: Tungsten Disulfide (WS2) or Tungsten Disulphide is an extremely slick, dry film lubricant coating. WS2 has an extremely low coefficient of friction of 0.03 -- lower than that of Teflon, Graphite, or Molybdenum Disulfide (MoS2). The film is remarkably durable comparing to many other lubricant materials and can withstand tremendously high loads of over 300,000 psi. WS2 has unsurpassed performance properties for lubricity, non-stick, low drag, wear life, and load rating. WS2 has an electrical conductivity in the order of 10-3 $(\text{ohm.cm})^{-1}$ [6]. With a half micron coating, the electrical/thermal resistance introduced by the coating will be negligible.

ANL is positioned well to investigate the properties of low friction lubricants because ANL has the expertise and the test facilities to perform required investigations. In addition, ANL possesses coating facilities to deposit special carbon or inorganic coatings by means of chemical vapour deposition, sputter magnetron deposition, or electron beam evaporation. With the material engineering expertise we have here at ANL, we can also investigate other vacuum compatible lubricants and/or surface process to further improve the performance of sliding contact cooling ILC positron source target system.

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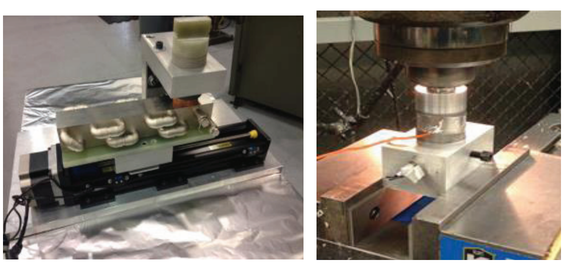
DEMONSTRITION TESTS AND PLANS

As we discussed in previous section, all the technologies we need are readily available for realizing this sliding contact cooling ILC positron source target system. Giving enough resource, for sure, we can build a working positron source target system based on this sliding contact cooling scheme. But due to the nature of this sliding contact cooling scheme, it's hard for us to forget about its similarities with friction braking system and convince ourselves that it won't act only as a brake and overload the motor or breakdown prematurely. In order to convince people, we need to take a step back and collect some hard evidences to prove that we will not be building a brake for the ILC target wheel.

Low Speed Linear Sliding Demonstration

As showing in Fig. 4a, the setup of low speed linear sliding demonstration consists of a copper block with cooling water channels, a copper cylinder with heating elements inside, a linear motor, a mounting fixture to fix the copper cylinder and applying pressure. Both surface of copper block and cylinder are coated with titanium nitride.



(a) (b)

Figure 4: Low speed linear sliding demonstration (a) and high speed spinning with friction test (b).

During the low speed linear sliding demonstration test, we were able to control the temperature rise of the copper cylinder by transferring heat (while sliding) from the copper cylinder to the titanium nitride coated copper block the block under the cylinder.

High Speed Spinning with Friction Test

As showing in Fig 4b, limited by safety regulation and limited resource, a very simple and preliminary rotating with friction test was done here at ANL to demonstrate the possibility of contacting cooling of ILC positron source target. Since cold welding may happen if two flat surface of identical material came into good contact, we purposely rotated a dry lubricant coated stainless steel surface against dry lubricant coated stainless steel surface at high speed to see if the dry lubricant, molybdenum disulfide, would work and prevent the two surface to form seamless bond. We spined the upper cylinder at 4000rpm for a minute. The the cylinders warmed up slightly, but no cold welding happens.

High Speed Sliding Contact Heat Transfer Demonstration Plan

Fig 5 shows a 3D model of our planned high speed sliding contact heat transfer demonstration.

The purpose of the high speed sliding contact heat transfer demonstration is to test everything except rotating in vacuum.

SUMMARY

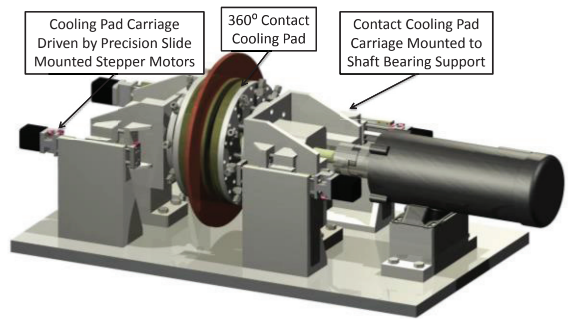


Figure 5: High speed sliding contact heat transfer demonstration.

A new ILC positron source target system using sliding contact cooling scheme has been proposed by ANL. This proposed new target system saved the potential failure of the original system by using a different cooling method which enabled the elimination of rotating vacuum seal and improving the target wheel support and balances.

ACKNOWLEDGMENT

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