# UPDATES ON THE SLIDING CONTACT COOLING ILC POSITRON SOURCE TARGET DEVELOPMENT*

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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 magnetic torque coupler to drive the solid spinning wheel target. The energy deposited from positron production process is taken away via cooling pads sliding against the spinning wheel. A full size test wheel has been built and some initial tests have been done with promising outcomes. Results of these tests are presented in this paper along with a plan for developing a prototype.

## INTRODUCTION

The ILC baseline positron source [1] is a helical undulator based positron source which produces $2\times10^{10}$ 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 $3 \times 10^{10}$ 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]. Since the discrete target system requires a larger scale of changes to the current ILC positron source layout which is not preferred, we proposed a sliding contact cooling based system [4].

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.

Unalike the original ILC positron source target cooled with water flow inside the target wheel, we use spring loaded cooling pads sliding against the target wheel to take away the energy deposited in target resulting from positron production. Inside the cooling pads are cooling channels with cooling liquid flowing constantly. Since 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 rotating target wheel which require feeding cooling water through the shaft and thus a rotation water union. One step forward, with a magnetic torque coupler to couple the rotation of target wheel and motor, we enclosed the whole target system inside a vacuum chamber and eliminated the needs of rotation vacuum seal altogether.

The proposal for developing a sliding contact cooling ILC positron source target was funded and our phase one of the project is a success. The results of phase one and a plan for phase two is presented in this paper.

## PROPOSED PARAMETERS AND PLANS

### Proposed Parameters

The target will be a 1 meter diameter solid disc with a rim of about 2cm wide and 1.4cm thick titanium alloy for positron production. The disc surface area contacting with cooling pad will be coated with vacuum compatible low friction lubricant. The cooling pad will be spring



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loaded and also coated with vacuum compatible low friction lubricant.

The contacting area is assumed to be 300cm$^2$ with a contact pressure of 1N/cm$^2$. Assuming a friction coefficient of 0.1, the heat generated by the friction is estimated to be 3kW when target is rotating at full speed (~2000RPM).

If Tungsten(173 W/m/K) is used for the cooling pads, then the temperature at the surface of target will be roughly estimated at about 38K above ambient for 20kW total power removal( the highest power deposited in target by photon beams is about 8kW [4]). The cooling pad will have cooling channel inside and connected with cooling liquid manifolds. As the cooling pad is stationary, a vacuum compatible cooling water manifold should be easily implemented.

### *Plans*

The first factor for this scheme is to eliminate the need of rotational vacuum seal for the rotational shaft driving the wheel. The 2nd factor is to cool the wheel using the heat transfer between the stationary cooling pads and the spinning target wheel. For our phase one of this project, we planned to demonstrate the vacuum compatible mechanical driving system which will enable us to eliminate the rotational vacuum seal for driving shaft.

After phase one is completed and successful, we planned to demonstrate the heat removal from the spinning target at full speed and under rough vacuum with the contingency of sufficient funding in phase two.

With the success of phase one and phase two, we have both of those two factors covered and a functional prototype for system integration and radiation shielding engineering will be our planned deliverable for phase three if we will be funded to that point.

Beyond the end of phase three, we will be collaborating with other institutes to complete the integration of the final undulator based positron source target system.

## PHASE ONE AND BEYOND

### *The Mechanical Driving System*

The most trivial and compact solution would be modify a permanent magnet AC motor to mount the rotor in a vacuum tight sleeve and thus the rotor can be rotating inside the vacuum. But this approach requires more engineering efforts because there is no commercially available product that can be easily modified. A less compact but more practical solution is to use a magnetic torque coupler with a commercial AC induction motor to drive the target wheel without physical connection between the wheel and motor and thus eliminated the rotational vacuum seals.

Magnetic torque coupler uses the interaction between magnet driver and follower to transfer forces without touching and it allows for the insertion of a mechanical barrier between the driver and follower to separate environments. The magnetic torque coupler has been used in high power pumps. And for a good starter, we purchased a pump utilizing magnetic coupler and used it in our project with some little modifications as showing in Fig. 1.


Figure 1: Picture showing a modified pump with magnetic torque coupler driving a solid aluminum wheel.

### *Wheel and Cooling Pads*

The wheel for phase one and two is a simple solid aluminum disc with one meter diameter and 5.08cm thickness. A production target wheel with 1.4cm thick and 2cm wide titanium alloy rim will be engineered during phase three.

Two set of simple cooling pads were designed and built. As showing in Fig. 2, the cooling pads are spring loaded and riding on a carriage sliding on two linear slides. The carriage is connected to a linear actuator with a load cell. By changing the position of the linear actuator, we are pushing or pulling the carriage and thus the cooling pad. The force applied will be read back via the load cell. We use the readout of load cell as feedbacks to control the pressure applied on the contacting surface.

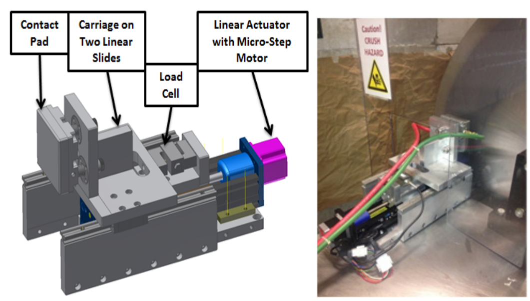


Figure 2: CAD model and picture of cooling pad assembly.

### *Instrumentations*

Since we are using AC induction motor, it is asynchronous and thus we need a tachometer to measure the actual speed of the spinning wheel. The tachometer we chose uses a frequency to analog coverter and a laser remote sensor. With this tachometer, we will be able to monitor the speed of spinning wheel through a window on the vacuum chamber in the final product.

To monitor the temperature of the wheel, we used two IR thermal sendors connected ADC so that we can read the temperature back into the computer to allow automatic data logging in our test and also will enable us with adaptative control of the cooling pads in the final product.

## TESTS AND RESULTS

The goal of phase one is very simple and straight forward. We span the solid full size wheel with two cooling pads sliding on the wheel for many hours at ~100RPM which proved that the magnetic torque coupler we purchased is strong enough to drive the target wheel and there will be no problem for us to drive the target wheel in vacuum without any rotational vacuum seal. We extended our goal of phase one a little bit while waiting for phase two funding and did few tests to demonstrate the heat removal by sliding contact cooling at low speed in the air.

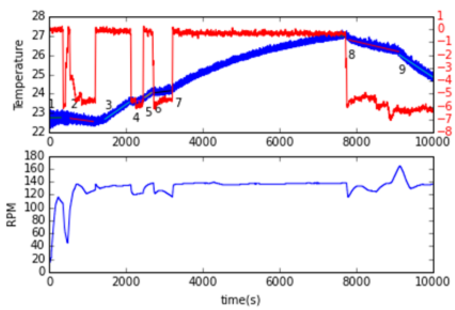


Figure 3: Typical results from low speed in air sliding contact cooling tests.

To demonstrate the sliding contact cooling at low speed in air, we used a radiant heater to heat the wheel and use the cooling pads to extract the heat while spinning the wheel at about 100RPM. As showing in Fig. 3, we started with spinning the wheel without heating and cooling. No change to the wheel temperature observed. Then we pressed the cooling pads on to the wheel and we observed the descending of wheel temperature. Then we moved cooling pads away and turned on the heater and the wheel temperature started to increase. About 15 minutes later, we applied the cooling pads while the heater was still on and we observed that the increase of wheel temperature was stopped. As soon as we moved the cooling pads away from the wheel, the temperature backed on to its uprising trend. We repeated previous step short time later just to confirm previous observation. We then let the heater on without applying the cooling pads for about one hour and the temperature of the wheel reached about 27°C. We applied the cooling pads while keeping everything else the same and we observed a clear cooling effect. We observed a temperature drop of about 1°C in about 25 minutes. We then kept the cooling pads sliding on the wheel while the heater was powered off and removed. Since the heater has been removed, the wheel was cooling down at a faster rate. Using the rate of changing of temperature, we roughly estimated that the heating power is about 110W when heater set on medium and about 240W when heater was on high. The estimated cooling was ranging from 14W to 240W for different measurements which has indicated that we need better mechanical design on the cooling pads supporting system

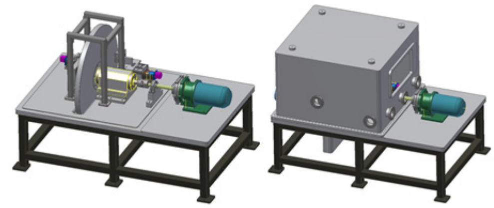

Figure 4: Phase two conceptual design CAD model.

and there are still rooms for performance improvements on the cooling pads.

## CONCEPTUAL DESIGN OF PHASE TWO

Even though we have conceptual design of phase two as showing in Fig. 4, the reality is that phase 2 needs funding for engineering and design to be performed in conjunction with safety analysis. Engineering solutions that satisfy the safety requirements will drive the overall design of Phase 2. Phase 2 will also need significant funding for vacuum components, drive components, controls, chillers, hardware, infrastructure, effort, etc.

## SUMMARY

The phase one of the new ILC positron source target system using sliding contact cooling scheme has been completed successfully. We proved that we can drive the full size target wheel using magnetic torque coupler which enabled us to eliminate the need of rotation vacuum seals. We also proved the concept of sliding contact cooling of the ILC positron source target system.

## ACKNOWLEDGMENT

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