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The ILC positron system uses novel helical undulators to create a powerful photon beam from the main electron beam. This beam is passed through a titanium target to convert it into electron-positron pairs. The target is constructed as a 1 m diameter wheel spinning at 2000 RPM to smear the 1 ms ILC pulse train over 10 cm. A pulsed flux concentrating magnet is used to increase the positron capture efficiency. It is cooled to liquid nitrogen temperatures to maximize the flatness of the magnetic field over the 1 ms ILC pulse train. We report on prototyping effort on this system.

1 Positron Source Overview

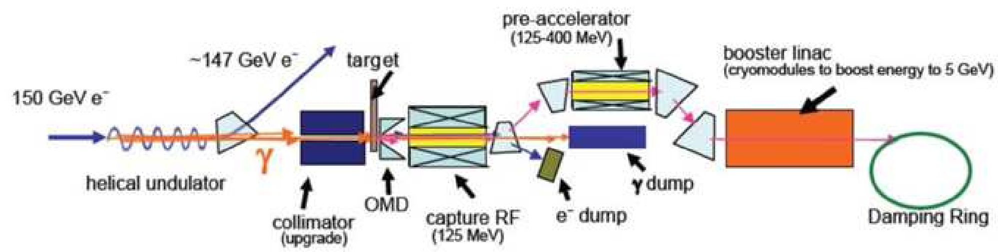

Figure 1: A schematic layout of the ILC positron source.

The ILC positron source [1] will be required to generate two orders of magnitude more positrons per second than any previous accelerator. As shown in Figure 1, the baseline positron system envisions passing the main ILC electron beam through several hundred meters of helical undulators in order to create a pulse of photons with energies in the 10's of MeV and over 100 kW of average beam power. The photons must then be passed through a target in order to convert a fraction of them into electron-positron pairs. This target must operate in a unique phase space compared to other target systems that have been fielded in the past. The average power that the target must dissipate is low compared to other systems but the power is concentrated into a small spot size and is deposited in a 1 ms time scale. The energy deposition in a stationary target would induce a stress in the target material which would exceed yield strength of the material and would fracture the target. The 1 ms timescale of the energy deposition makes it difficult to use motion of the target to distribute the energy deposition over a larger area. A target moving at 100 m/s will spread the energy deposition over a 10 cm stripe. In order to achieve this speed we have developed a target concept of a rotating titanium wheel that has a diameter of 1 m and rotates at 2000 RPM, as shown in Figure 2.

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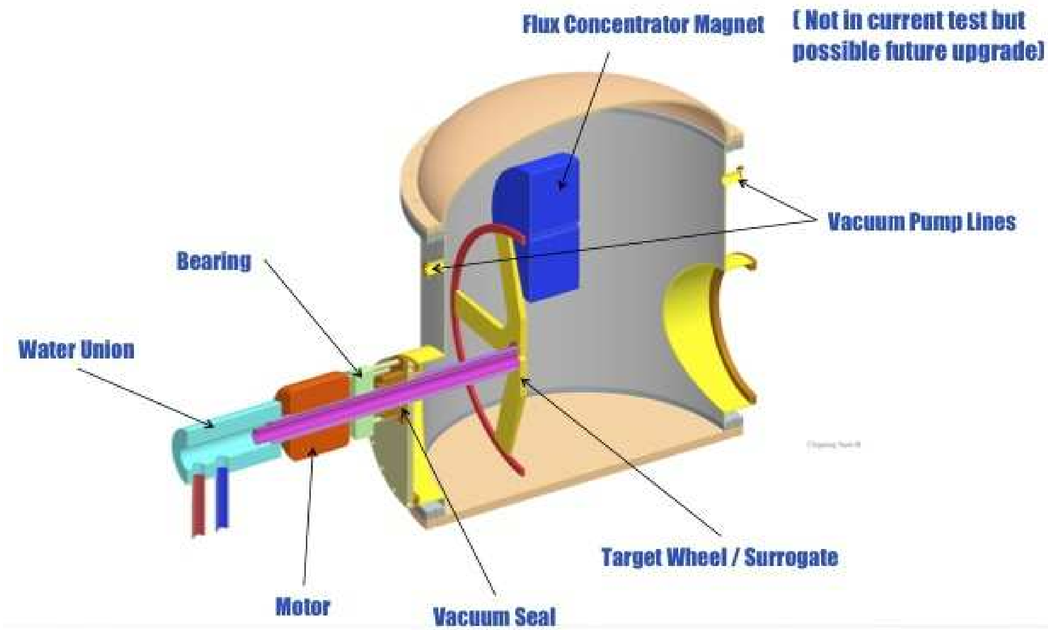

Figure 2: A schematic of the rotating target ferro-fluidic seal test stand.

Cooling water flows through a double-walled shaft to the target where it flows out each spoke, through a section of the outer wheel, and back down a spoke. The intensity of the electron-positron beam emerging from the target makes the creation of a vacuum window to separate the target volume from the subsequent accelerator sections difficult. No design has been found which can prevent such a vacuum window from melting during operation. Therefore the target volume will share the same vacuum as the subsequent capture accelerator sections in the positron source system. In order to have the rotating target in the same vacuum as the accelerator we will need to have a rotating vacuum seal for the shaft. Rotating vacuum seals based on ferrofluids exist and are available from a number of vendors. A fluid with suspended magnetic particles exists in a gap between two counter rotating sets of permanent magnets. This forms the vacuum seal. This solution must be prototyped and studied so that the out-gassing rate from the ferro-fluid can be measured to see if a solution for the vacuum pumping can be achieved. The ability of the seal to perform continuously for the planned 9 months of operation must also be determined.

A design for a pulsed flux concentrator has also been under study. These types of devices have been used before but usually with much shorter pulse lengths. This device will need to maintain a 1 ms flat top field during the ILC bunch train. A previous device [2] created at SLAC during the 1960's for a hyperon experiment, which was designed for a 40 ms pulse, was used as the basis for the ILC design. As well as maintaining a flat top during the ILC bunch train the device will need to be able to handle the radiation environment near the target.

2 Prototyping of the Ferrofluidic Seal

Figure 3 shows a ferro-fluidic seal purchased from Rigaku corporation. The outer ring is stationary and sealed to the vacuum chamber. The inner ring has a 3 inch inner bore through which the shaft can be mounted. The ferro-fluid exists in the gaps between the two rings.

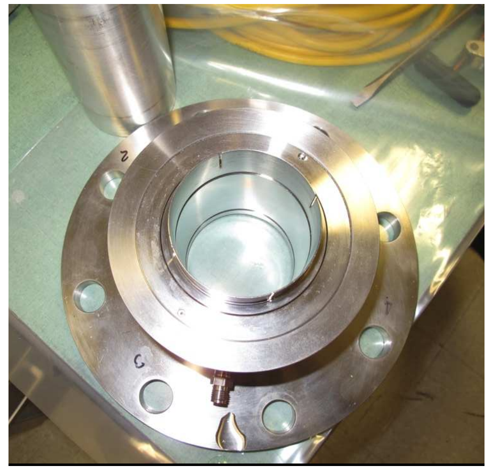

Figure 3: The RIGAKU ferrofluidic seal. The inner bore of three inches diameter allows the central shaft to penetrate the vacuum.

In order to test the out-gassing of the ferro-fluid into vacuum we modified an existing out-gassing test system to be able to mount the seal and rotate it at 2000 RPM. Initial commissioning of the system had problems rotating the seal at the full velocity, the drive motor would keep tripping off. Modifications were made to increase the available torque to drive the motor. The devices have a choice of the type of ferro-fluid that is used and what type of permanent magnet. We initially chose a seal with the more radiation hard permanent magnets and a more viscous ferro-fluid which should reduce out-gassing. However, a more viscous fluid also increases the torque in the system and thus the energy deposited in the ferro-fluid. While it was rated to be able to run at 2000 RPM the Rigaku sealed failed after about 15 minutes of running at 2000 RPM. It is believed that this is a heating effect and the seal was returned to Rigaku for post-mortem analysis. A second plug-compatible seal was sourced from FerroTec with a reduced viscosity ferro-fluid for testing.

In parallel, construction of the full rotating shaft test stand is underway. The detailed design drawings for the shaft are shown in Figure 6. The shaft is composed of two concentric pipes to allow cooling water to flow to and from the shaft. A rotating water union is attached to the end of the pipe to mate with the outside water supply. We plan to use the prototype titanium wheel that was created by the University of Liverpool for eddy current testing at the Daresbury lab. Since it was not created with cooling channels the cooling water will only flow down the pipe and back. The ferro-fluidic seal is mounted on the bulkhead of the vacuum tank that we are using for this test. Farther down the shaft is a bearing block to provide support for the shaft

Figure 4: A test stand to do out-gassing studies of the ferro-fluidic seal while rotating at 2000 RPM.

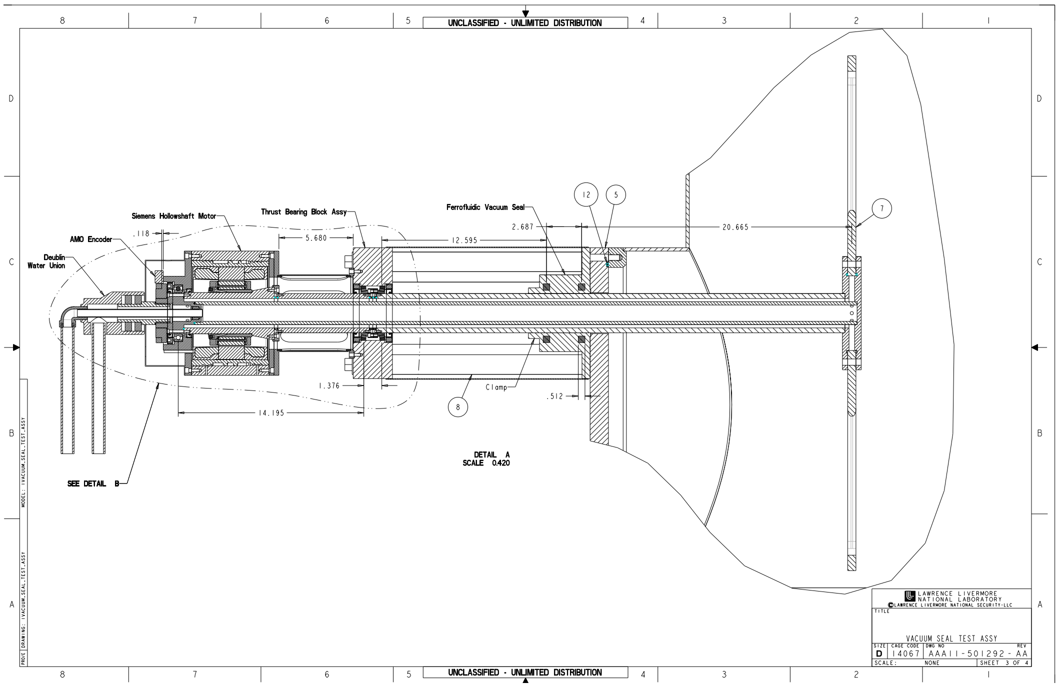

Figure 6: Assembly drawings for the target shaft assembly.

and target. A Siemens hollow shaft motor completes the assembly and will rotate the shaft at 2000 RPM.

As of LCWS11 we had commissioned a vacuum tank as shown in Figure 5 and had received all of the manufactured parts for assembly of the shaft. Commissioning of a data acquisition and slow control system was ongoing. The long term testing will continually monitor cooling water flow rates to the ferro-fluidic seal and Siemens motor. Temperature monitors will be in place on the ferro-fluid seal, bearing block and motor as well as the cooling water. Three-axis vibration sensors will be mounted on the ferro-fluid seal, bearing block and motor. We will use this to monitor any degradation in the bearings over time.

Figure 5: The vacuum tank at LLNL being used for the rotating seal test.

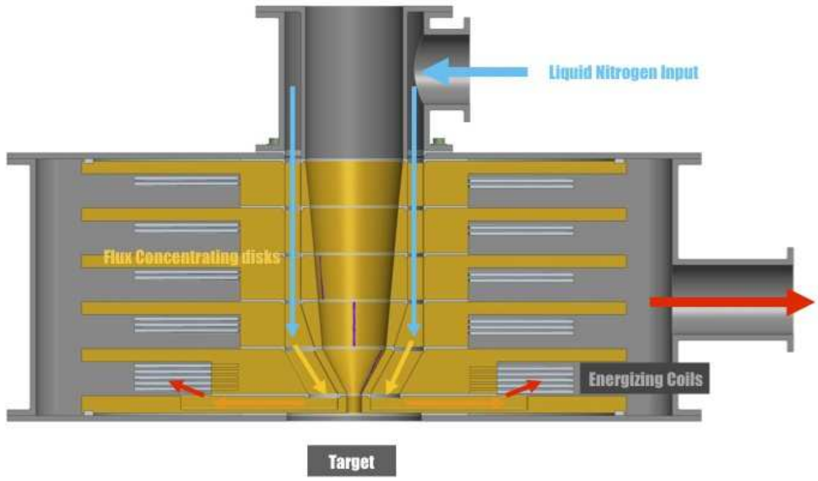

Figure 7: Schematic of the pulsed flux concentrator. Energizing coils induce a current in the concentrating plates to create the magnetic field in the bore. The entire assembly is bathed in liquid nitrogen to reduce the electrical resistance of the plates and help maintain the current over the 1 ms ILC bunch train.

3 Prototyping of the Pulsed Flux Concentrator Magnet

A pulsed flux concentrator (PFC) is basically a transformer where a set of energizing coils induces a current in a set of concentrating plates. Figure 7 shows the six concentrating plates interleaved with the five energizing coils. Figure 8 shows an example of one of the concentrating plates. The insulating gap that runs from the bore to the edge is critical to successful operation. Without a gap the induced currents in the plate would have the opposite sense as the currents in the coils and would cancel the magnetic field generated from the coils. The insulating gap from the bore to the outer edge prevents current from circulating around the outside edge and forces the current to travel around the bore in the same sense as the coils. This has the effect of concentrating the field from the coils into a smaller cross-sectional area and creating a higher field in the bore. One of the limitations of this technique is that currents in the plate will dissipate over time due to ohmic resistance losses in the plate reducing the field. On a long enough timescale the currents in

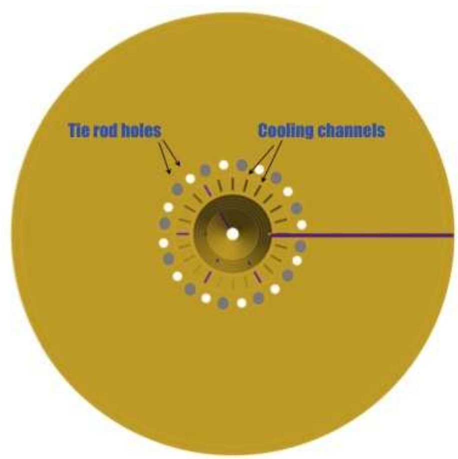

Figure 8: One of the flux concentrating disks. An insulating layer forces the induced current to flow around the bore.

the concentrating disk will fall to zero and the field will return what would be induced by just the energizing coils. For this application we would like to have a reasonably constant field over the 1 ms pulse length of the ILC bunch train. Therefore we plan to use OFHC copper and cool it in a liquid nitrogen bath in order to decrease it's resistance and increase the usable length of the pulse.

The site of highest energy deposition from operation of the device is in the concentrating plates near the bore of the magnet where the currents are highest. The first concentrating plate dissipates about 300 W and the second concentrating plate dissipates about 500 W at full 5 Hz operation. In order to provide the best cooling in this region a set of cooling channels are designed to run along the bore from the back end of the device to the front and then discharge into the larger liquid nitrogen bath. The cooling channels are designed as slits that are positioned radially around the bore as shown in Figure 8. This design requires an insulating seal between the concentrating plates to allow the cooling fluid to flow between the concentrating plates and to create a vacuum seal between the magnet bore vacuum and the liquid nitrogen bath. This is an extreme technical challenge as the seal must be electrically insulating, radiation hard, and able to withstand repetitive impacts from the 5 Hz pulsed operation. We have created a concept for a seal based on flexible graphite to create the radiation hard seal with a layer of Zirconia Toughed Alumina to provide the radiation hard electrical connection. Initial prototyping test will be carried out to determine if this is a viable solution.

The creation of a liquid tight cavity for the nitrogen bath also requires that the gap in the concentrating plate be filled with a radiation hard electrical insulator that can be bonded into place to form a liquid tight seal. This bond will be a site of high stress during the pulse. The requirement that this bond survive 100 million pulses over the 9 months of operation leads to a design choice of Zirconia Toughed Alumina. This material should be able to survive the repetitive stress. This may be difficult to manufacture and we are searching for vendors who can do this type of braze.

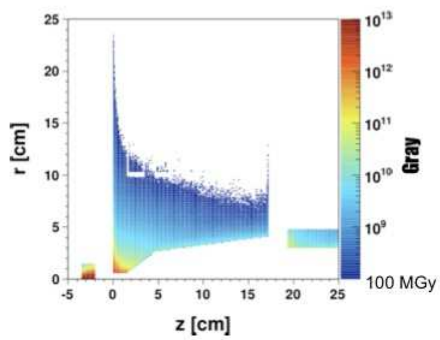

Figure 9: A Monte Carlo simulation of radiation deposition in the material of the pulsed flux concentrator from DESY/Zeuthen over 9 months of ILC running. The 100 MGy line is the limit for using organic insulators. All insulation of the plates at higher radiation levels must use ceramics.

The device sits a few centimeters from the target and is exposed to the radiation field from the device. Electrons, positrons and photons will emerge from the target and hit the device. Figure 9 [3] shows the expected dose in the device for 9 months of operation as a function of position. At the front face of the device, which is directly exposed to the charged particle flux, the dose can be TeraGray. The solid copper material of the disks provides for self-shielding of the charged particles and dose falls off rapidly. However the photon flux from the target is harder to shield against. Photon conversions will provide a radiation flux at all distances falling off as distance squared and from the shielding effect of material in the path of the photon. The energizing coils and concentrating plates will need to be electrically insulated from each other. The organic insulator with the best radiation survival is Kapton which is rated out to 100 MGray. From Figure 9 we can see that it may be usable as an insulating material on the energizing coils but is unusable anywhere closer to the bore of the device.

4 Future Work

As of LCWS11 the out-gassing test stand for the ferro-fluidic seal was being commissioned and the full rotating shaft test stand was under construction. Assembly drawings for the pulsed flux concentrator were being started and a set of prototype tests of the seals for the liquid nitrogen containment were planned. Once component testing is complete we will proceed to create a pulser to drive a prototype magnet at full current but reduced repetition rate and create a prototype magnet with the important features that will be required for realization of a final device at ILC.

5 Acknowledgments

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