Redesign of ILC Undulator Based Position Source Target System

Wei Gai,
HEP, ANL
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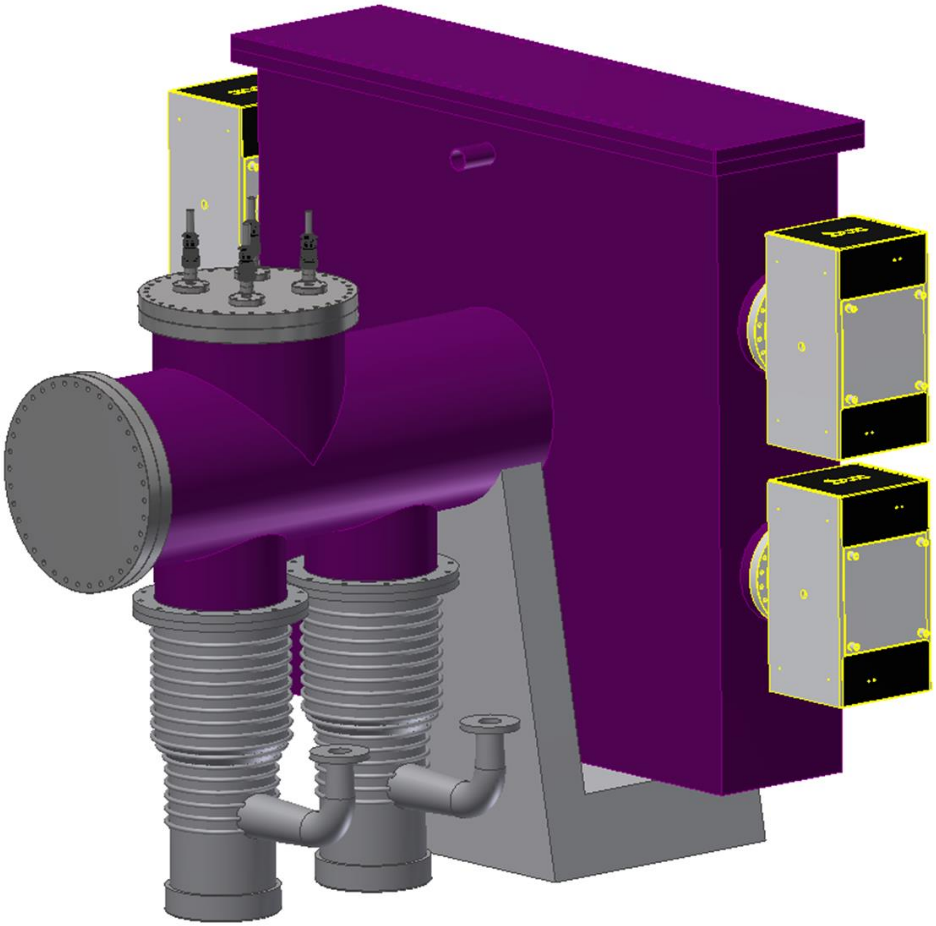
The ILC TDR baseline target system

- The 1ms ILC photon beam pulse would fracture a stationary solid titanium target.
- We have never been able to design a window between the target and the positron capturing system.
- We have to remove the power deposited in the target.

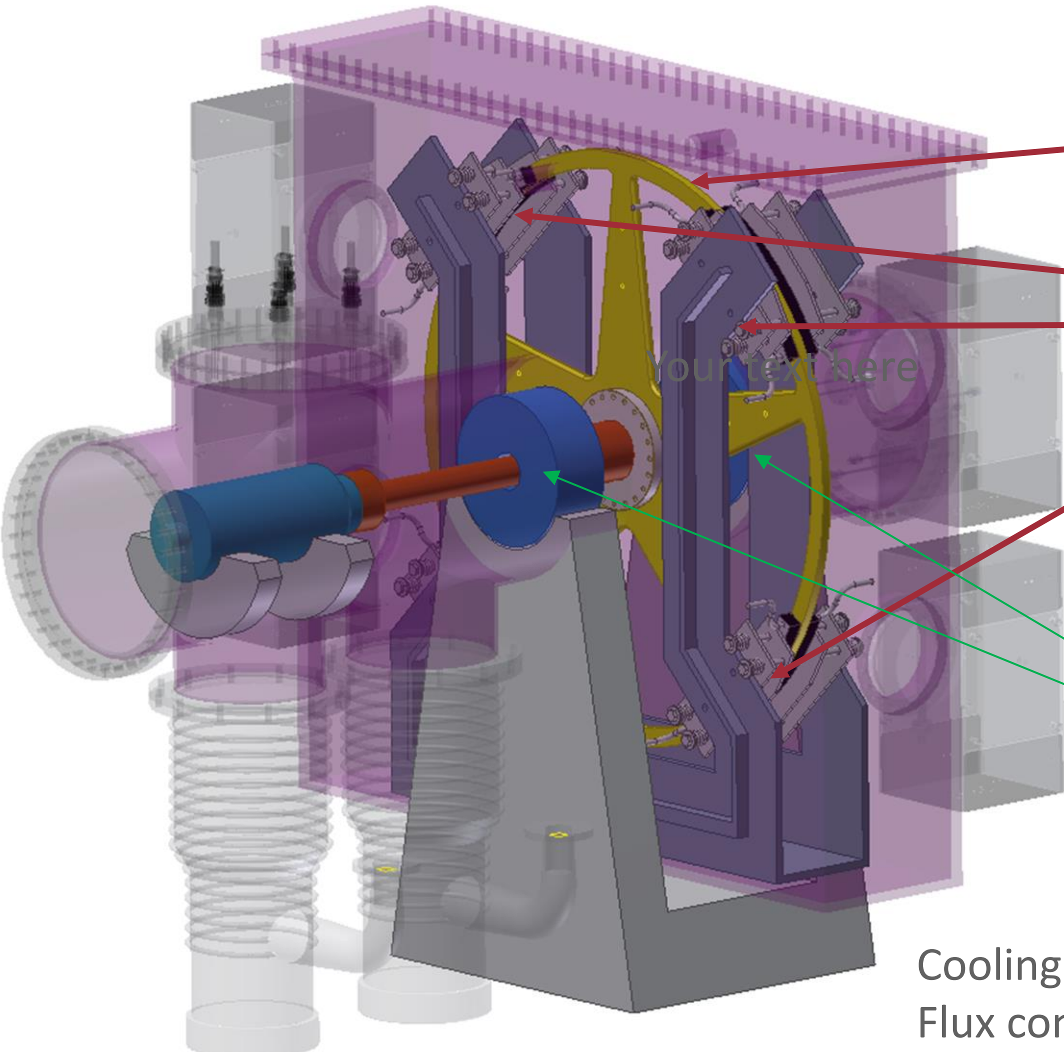
What if we:

- Eliminate the rotating vacuum seal by putting the whole target system in vacuum chamber.
- Eliminate the need of rotating water union and the complicated cooling channels in target wheel by using conduction cooling from spring loaded cooling sliding pads
- Eliminate rotating vacuum seal that enable us to support the shaft on both ends without concerning the vacuum.
- Eliminating the cooling channels in target wheel could simplify the target wheel design process and allows more freedom on optimization.

Looking from outside,
-A vacuum chamber without external drive except electrical and cooling water feed-throughs



Inside the chamber



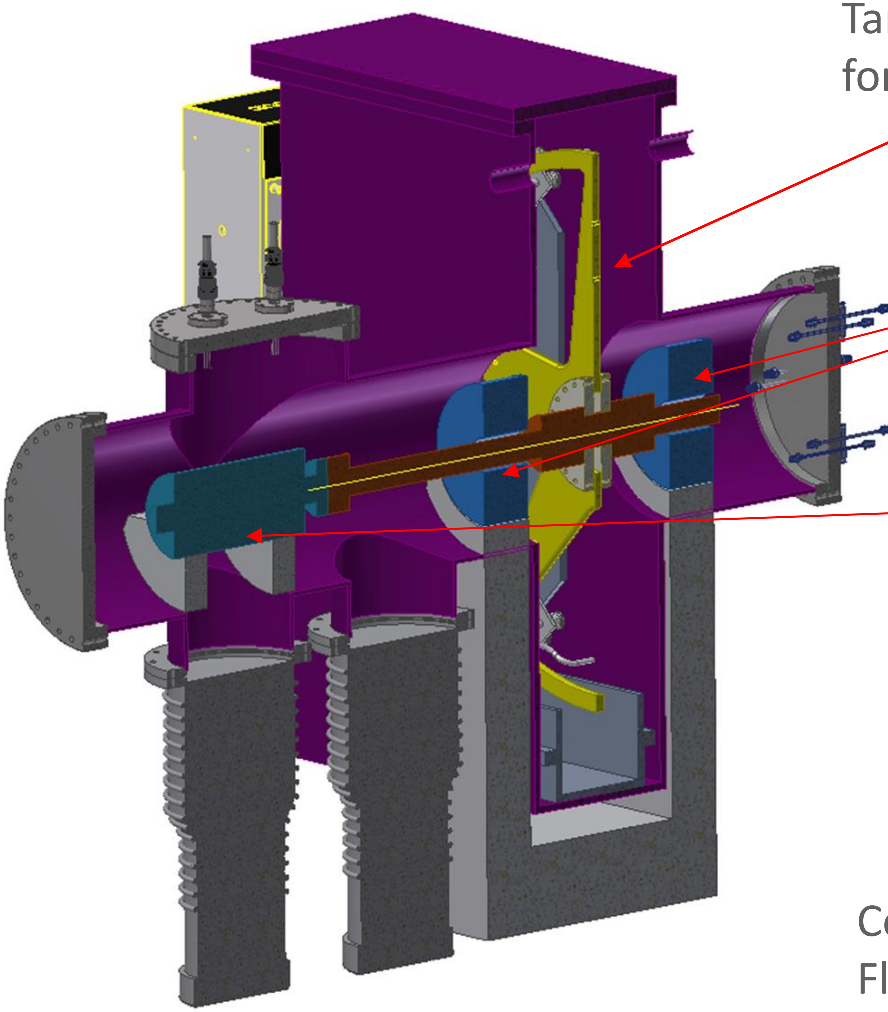
Target wheel, geometry may be optimized for cooling efficiency and wheel balance

Cooling pads and supporting structures

Magnetic bearing on both sides

Cooling water manifolds are not showing. Flux concentrator and accessories are not included in this conceptual illustration.

Cross section view



Target wheel, geometry may be optimized for cooling efficiency and wheel balance

Magnetic bearing on both side

Vacuum compatible motor

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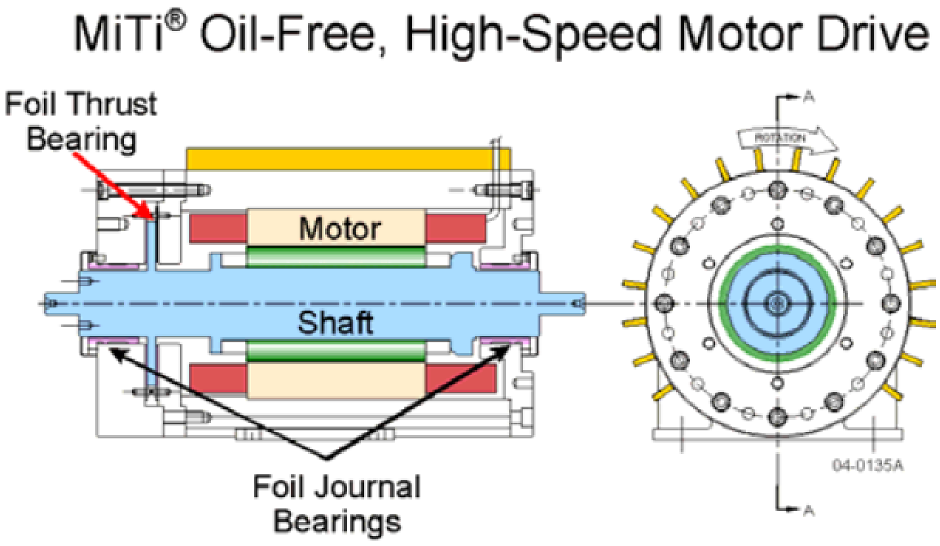
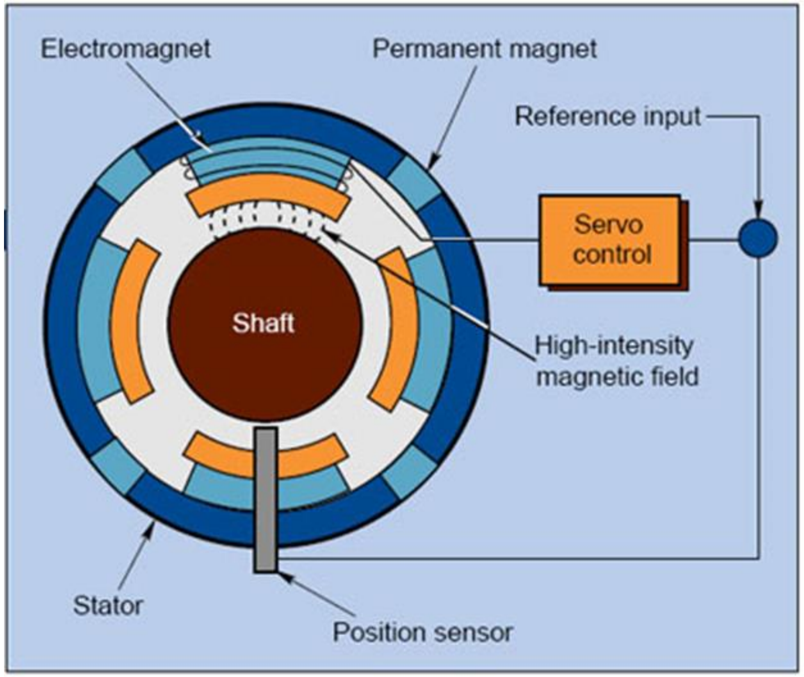
Vacuum compatible electrical motor

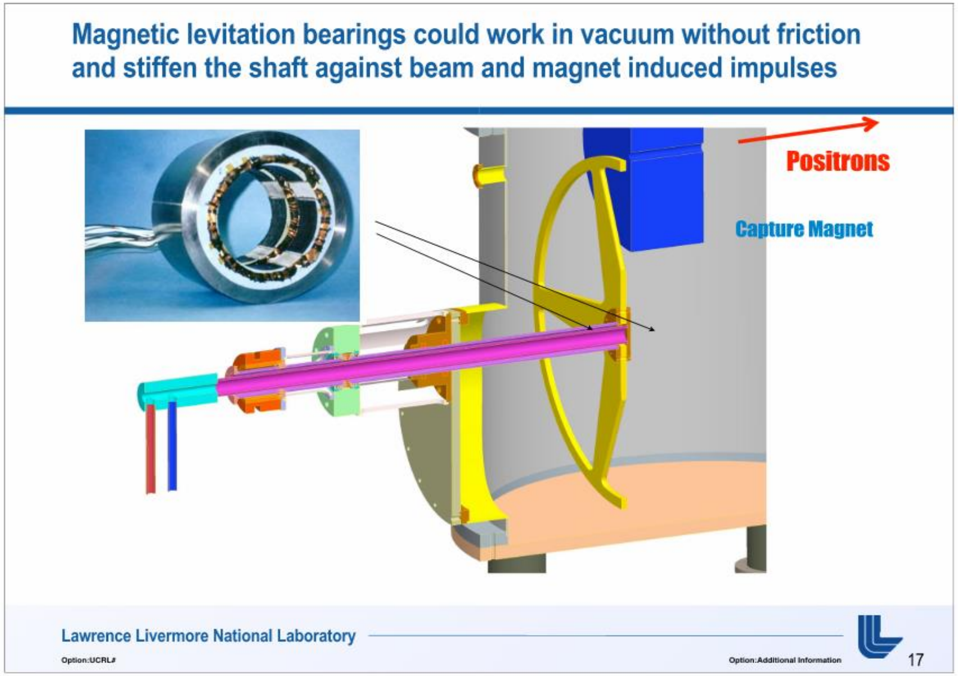


One needs to remember that magnetic motor does not require lubrication itself as long as bearings are lubricated correctly. We consider a motor drive that is oil free and maintenance free.

Through the web search, we found the MiTi®'s 32 kW, 60,000 rpm Oil-Free, High-Speed Motor.

Magnetic bearing

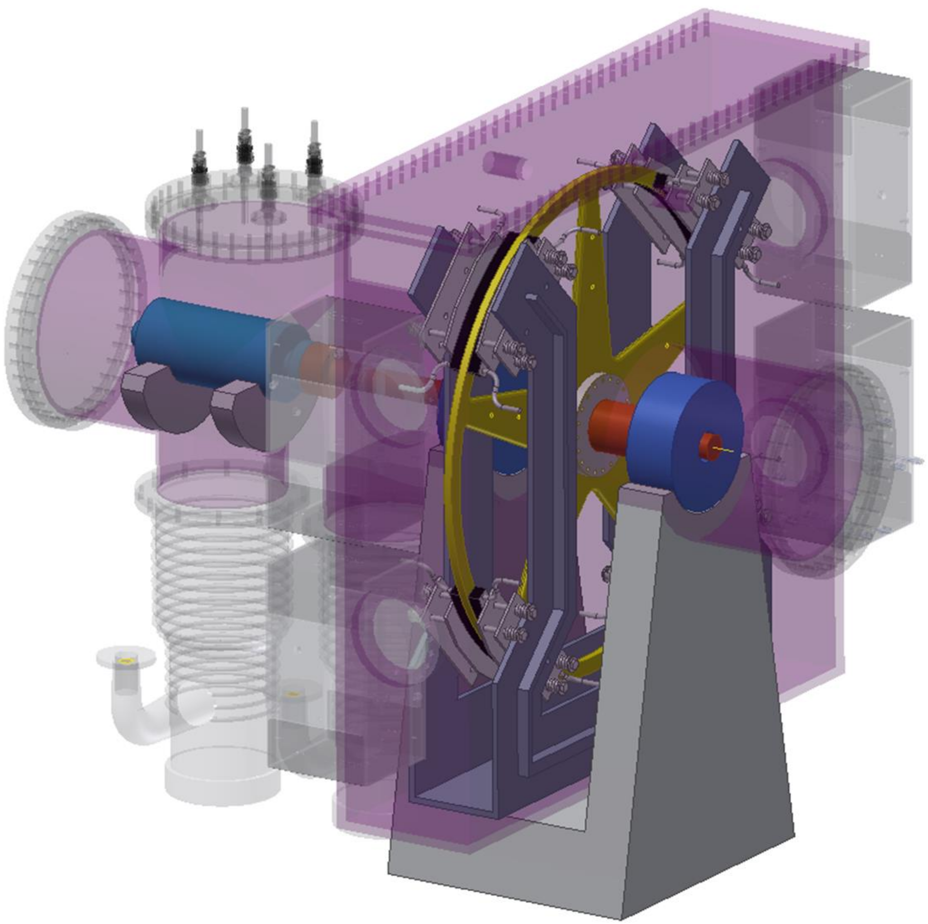




The principle of magnetic bearing is simple, it has been used extensively in aerospace industry.

Active bearing basics. Electromagnetic fields support moving parts without contact; servo control system stabilizes suspended element by increasing supporting force in direction opposite that of any displacement, to restore correct position.

Conduction cooling using spring loaded sliding pads for cooling



- By using the spring loaded cooling pads in close contact with the target rim, we can easily remove the power deposited in target.
- As we removed the need of cooling water channel inside the target wheel, we eliminated the need of feeding cooling water in the shaft and thus eliminated the need of rotating vacuum seal altogether and make it possible to have the target system enclosed completely inside a vacuum chamber with only electrical connections and stationary cooling water feed through.

The friction between target wheel and cooling pad

- The friction between target wheel and cooling pad could be minimized with vacuum compatible coated wear resist films, such as MoS_2, WS_2 or even advanced diamond like composite materials.
- WS_2: is a magic material, which has following properties: Tungsten Disulfide (WS_2) or Tungsten Disulphide is an extremely slick, dry film lubricant coating. WS_2 has an extremely low coefficient of friction of 0.03 -- lower than that of Teflon, Graphite, or Molybdenum Disulfide (MoS_2). The film is remarkably durable compared to many other lubricant materials and can withstand tremendously high loads of over 300,000 psi! WS_2 has unsurpassed performance properties for lubricity, non-stick, low drag, wear life, and load rating.
- WS_2 has an electrical conductivity in the order of 10^{-3} $(ohm.cm)^{-1}$ [1]. With a half micron coating, the electrical/thermal resistance introduced by the coating will be negligible

[1]. P. A. Chate, D. J. Sathe and P. P. Hankare, Electrical, optical and morphological properties of chemically deposited nanostructured tungsten disulfide thin films. Appl Nanosci (2013) 3:19–23, DOI 10.1007/s13204-012-0073-0

Proposed Parameters

- The ILC target rim has area of > 1000 cm^2 and will be coated with WS2.
- The cooling pad will be spring loaded and also coated with WS2.
- The contacting area is assumed to be 300cm^2 with a contact pressure of 1N/cm^2 (1.45psi). The heat generated by the friction is estimated to be 3kW.
- If Tungsten(173 W/m/K) is used for the cooling pads, then the temperature at the surface of target will be estimated at about 38 K above ambient for 20kW power removal.
- The cooling pad will have cooling channel inside and connected with cooling water manifolds. As the cooling pad is stationary, a vacuum compatible cooling water manifold should be easily implemented.

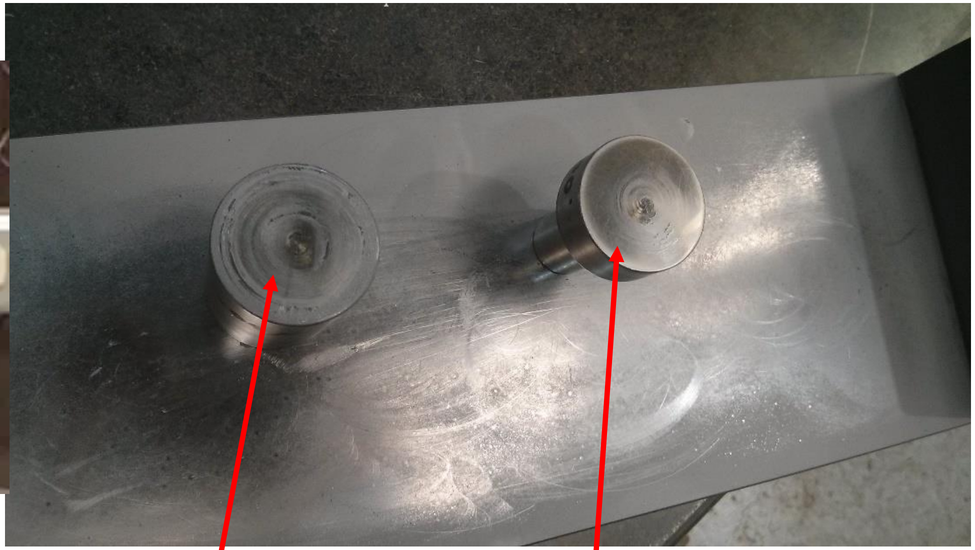
R&D issues and Risks

- R&D issues:
  - Design a vacuum chamber that can house 1 meter wheel with cooling system implemented on the outer wall and pads.
  - Purchase a vacuum compatible motor capable of 10 kW, and 4000 rpm.
  - A set of magnetic bearing to support the shaft with TI wheel. Or use the WS2 coating if ball bearings are used.
  - Gain experience on WS2 coating.
- Risks: Based the data we find, we could not identify any major risk associate with the design. However, we would like to prototype the system on the full scale to gain the experiences on
  - Lifetime of the WS2 coating;
  - Vacuum compatible motor selections;
  - Heat removal from a high vacuum chamber;
  - Stabilization of wheel with magnetic bearing/WS2 coated bearing;
  - Eliminate any unwarranted concerns on the undulator based source

Test of rotating with friction

- Limited by safety regulation and given a very short preparing time, 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 prevent the two surface to form seamless bond.

Test of rotation with friction @ 4000rpm for 1minute.

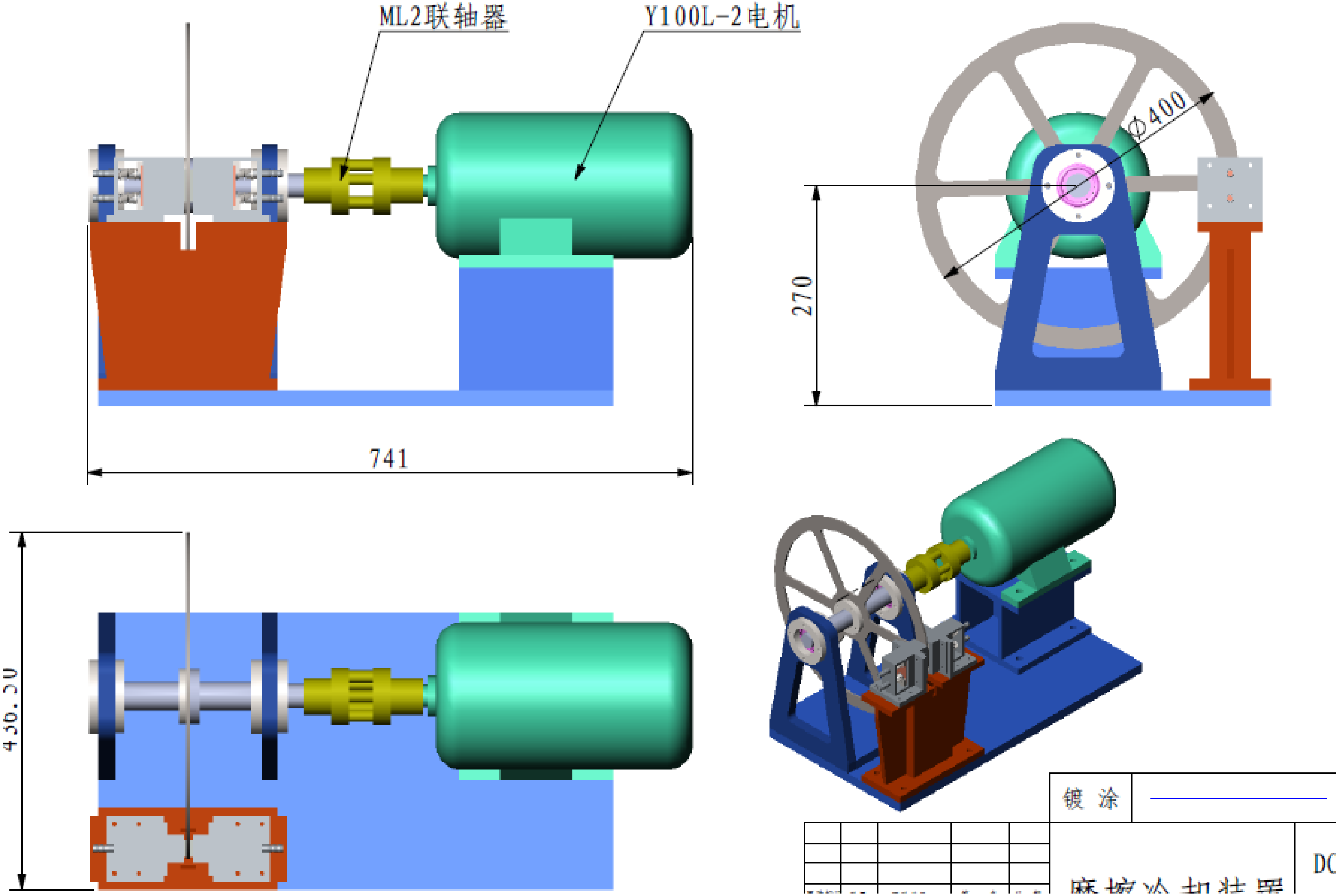


Stationary surface and rotating surface after test

- The machine was zeroed when two surface came into natural contact, the upper rotating cylinder sitting on the lower stationary cylinder, and then pushed in by half micron before rotating.
- The upper cylinder has been rotating at 4000rpm for 1 minute and cylinders were warmed up slightly but no cold welding.
- Inspection of the surfaces after test shows few relocation of dry lubricant coating but the two stainless steel surfaces were still covered with dry lubricant.

Planned testing this year and status

- Friction test using WS2 coated stainless steel and hard aluminum,
  - Measure the friction coefficient of WS2 coating
  - Measure the thermal resistance of WS2 coating
  - Life time of WS2 coating
- Prototyping at two different places: IMP/China and ANL.
  - We having playing with surface polishing and MoS2 coating with some good results;
  - Testing wheels coated with different materials; durability and heat transfer.
  - Define the wheel base materials or pads, with collaborative works with ANL tribology group (R. Erck and G. Fenske).
  - IMP started purchasing components; ANL will purchase soon.
  - Both tests should start in six months (with or without fund).


ML2联轴器
Y100L-2电机
741
Φ400
270
镀 涂

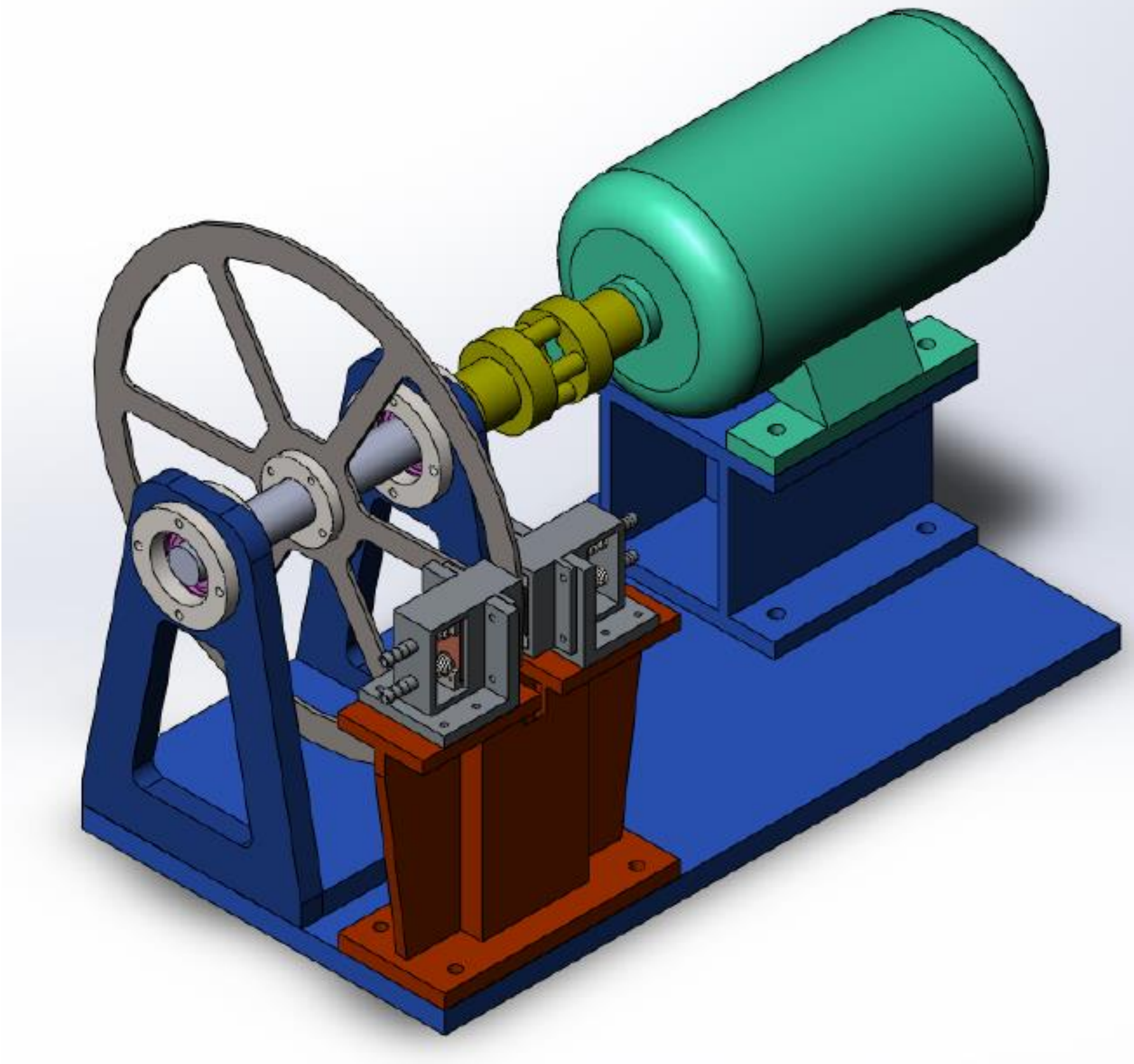
Specifications

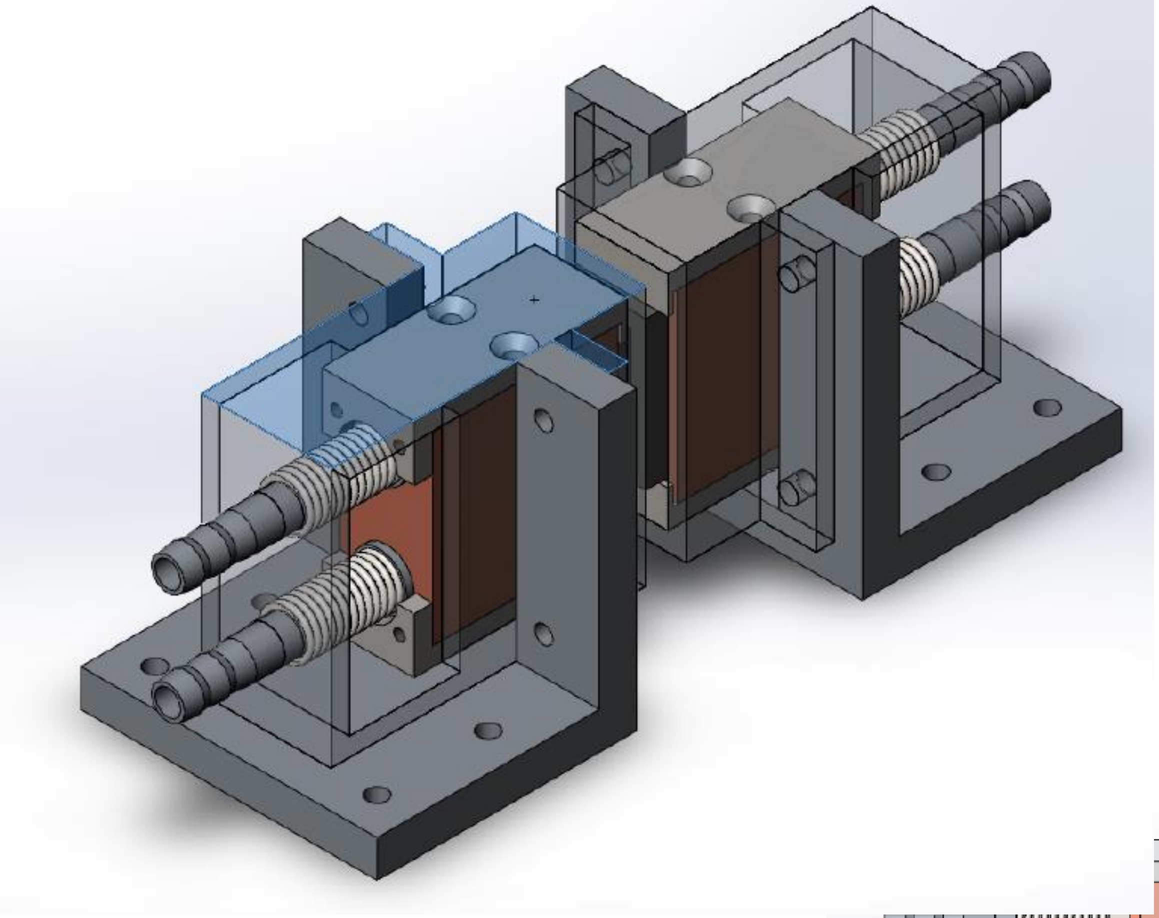
靶轮直径：**400mm**

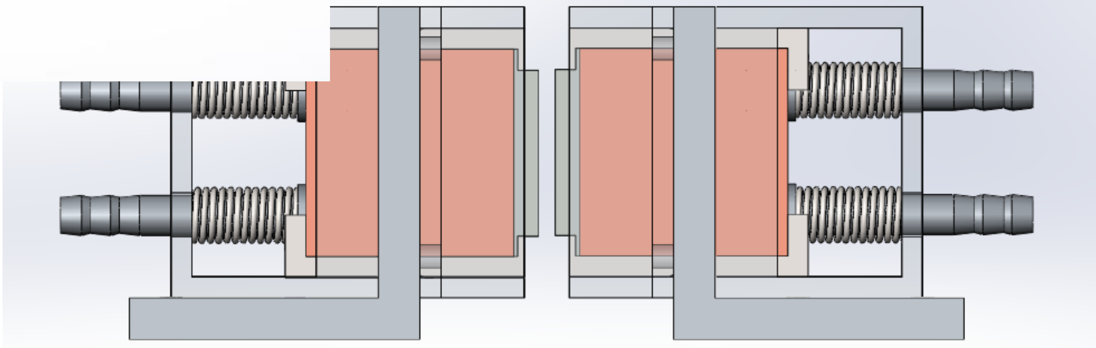
靶轮厚度：**3~4mm**

电动机功率：**2~3kW**

各种准直要求：0.2mm







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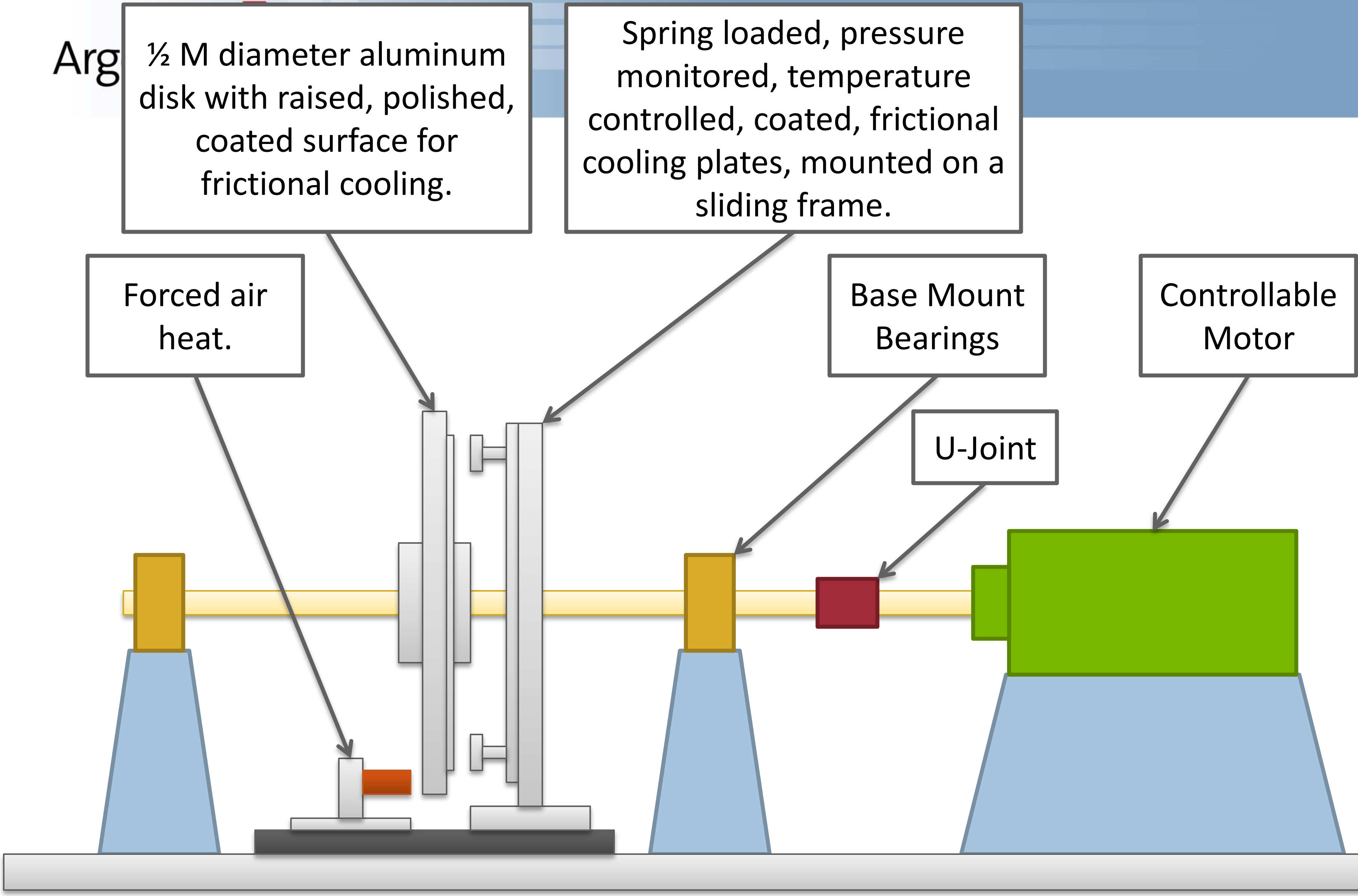
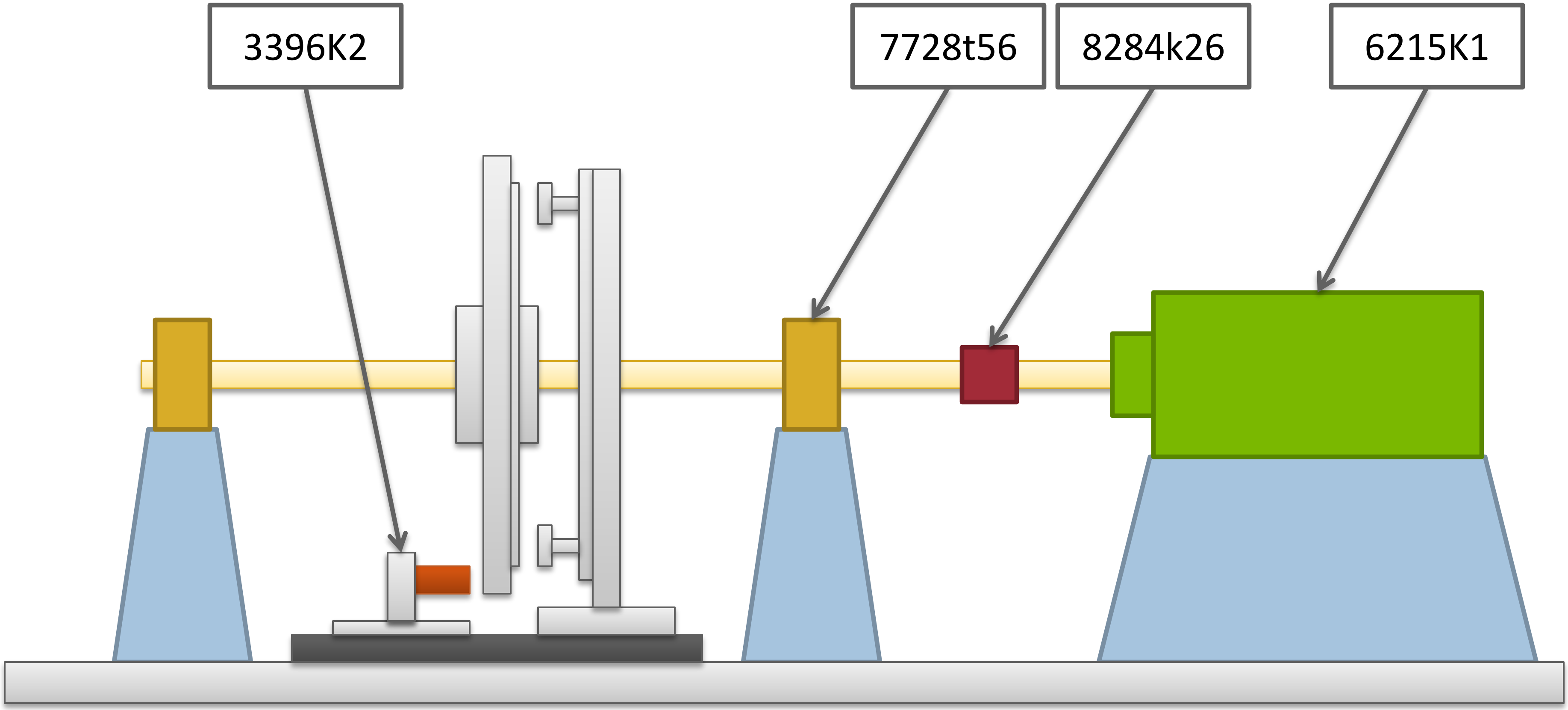


ILC Target Frictional Cooling Test Bed


3396K2
7728t56
8284k26
6215K1

What we can do at ANL (in material engineering)

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. ANL has over 20 years of tribological friction and wear capabilities, with a variety of test and characterization instruments. In addition, ANL possesses coating facilities to deposit special carbon or inorganic coatings by means of chemical vapor deposition, sputter magnetron deposition, or electron beam evaporation. Fig. 2 shows a photograph through the vacuum window of an ANL vacuum tribometer that can test samples in high vacuum, at temperatures to 500C, loads to 20 N, and sliding speeds to 5 m/s. It has the capabilities to measure durability and wear during a test by means of a position sensor.

Fig. 1. Graph of friction coefficient for dry sliding of hydrogenated amorphous carbon in high vacuum.

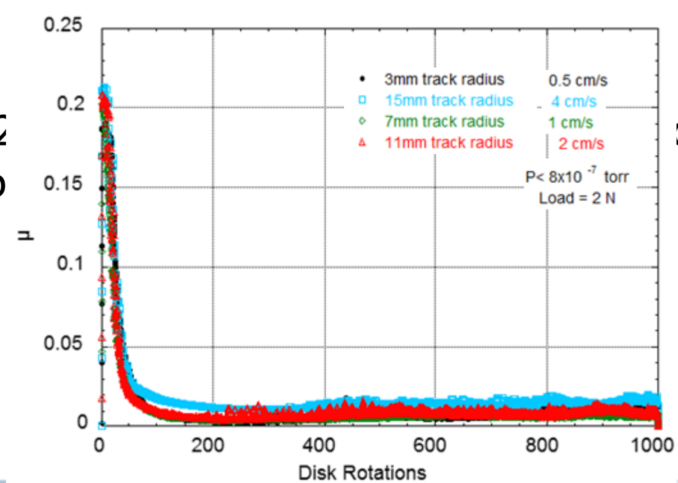


Fig. 2 ... dow of high-vacuum ...
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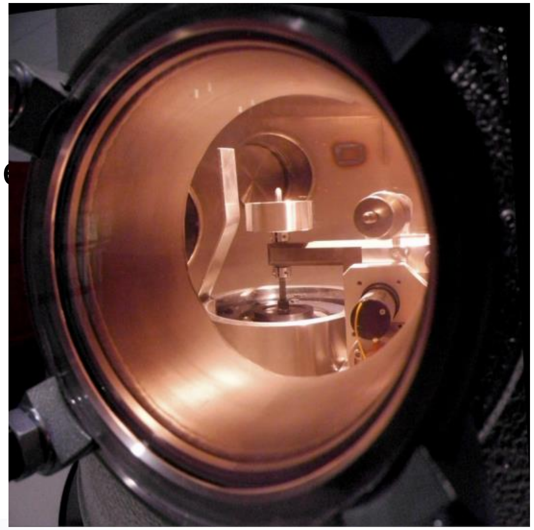

- Proposed activities -
- Investigation of different types of "solid lubricants." One type of solid lubricant is generically referred to as layered lattice compound: the molecular structure of the compound itself is macroscopically easy to shear and provides low friction. Another type of solid lubricant is carbon based such as diamond-like carbon or diamond. A third type supports a load and is easy to shear such as Ag or CaF2. Many of these materials/surfaces can be produced in-house and others can be obtained commercially.
- Tasks will focus on the simulation and validation of concepts using our vacuum tribometers. This will include generating wear and friction data to assure long durability and low friction coefficient.
- These tests will be performed in vacuum because the frictional and sliding properties of materials depend critically on the environment. The object of study is to develop a "system" (shoe material, rim material, and interface) which controls the sliding properties. The absence of adsorbing species in UHV profoundly affects the behavior of a system. In addition, the temperature of the sliding contact critically affects the sliding properties because the interaction of species is governed by temperature to a major extent.

Summary

- A new conceptual design for the ILC undulator based positron source conversion target is presented to solve the problems with the baseline target wheel.
- Key components and technology for the new design have been identified
- The initial study has not found any major risk with the new design
- Some initial tests have been planned and are carrying out.
- Full scale prototyping is in plan

We'll have a full featured target ready in 3 years with the contingency of enough resources.