ILC Undulator Based Position Source Target System

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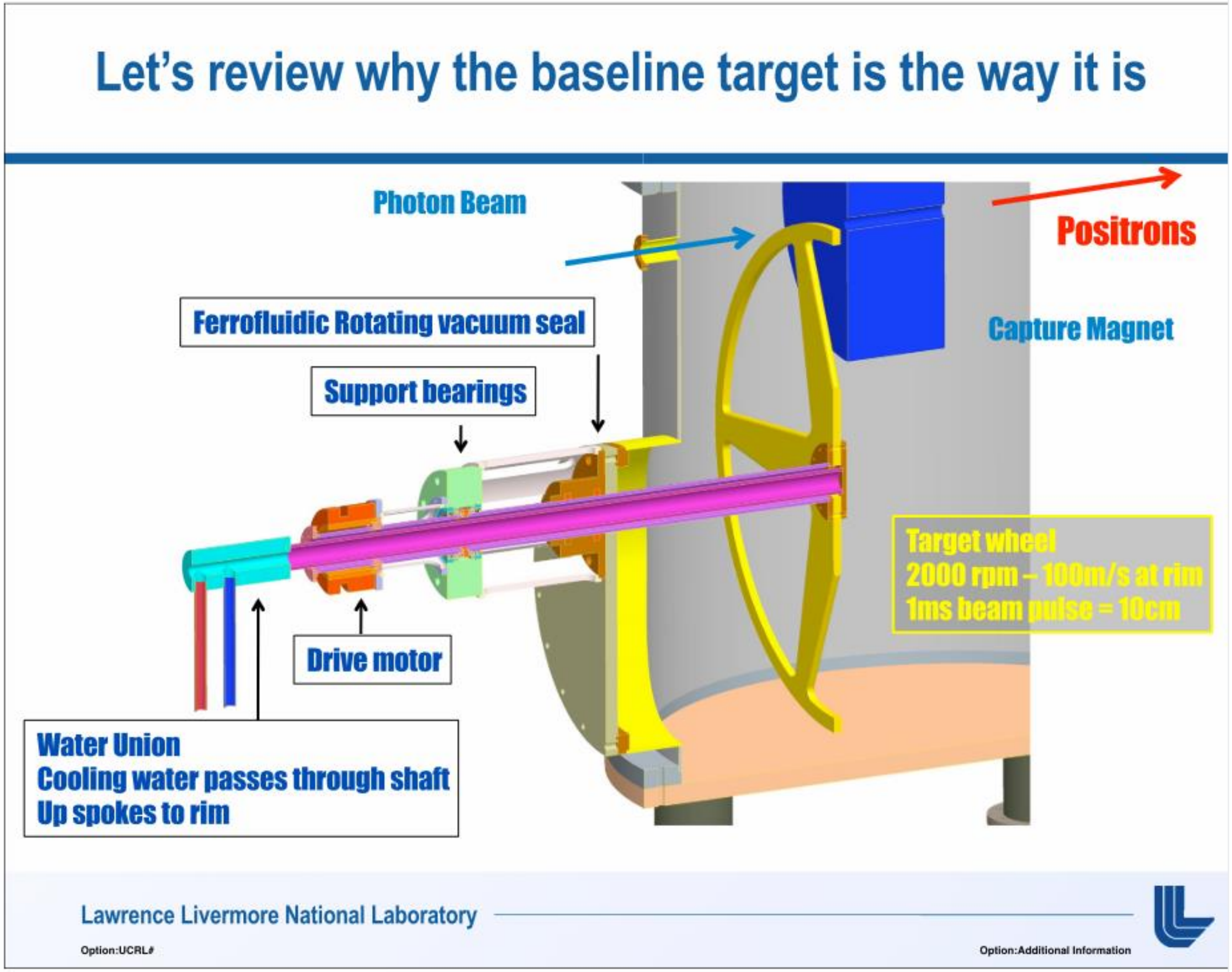
What we have accomplished in the last decades:

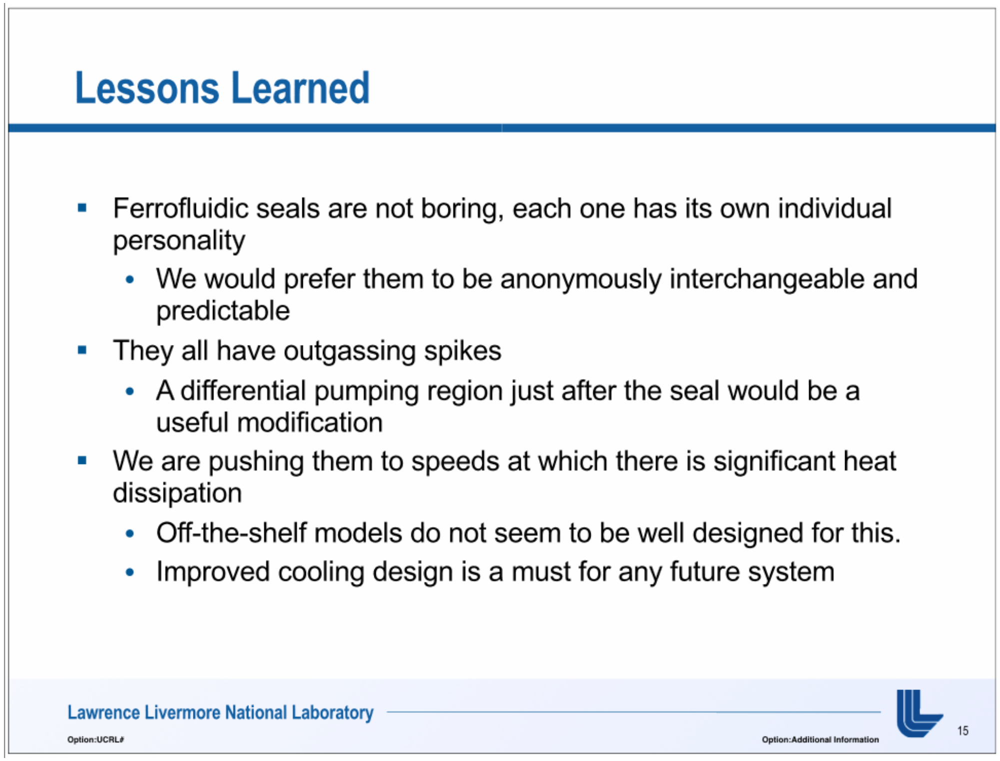
- In the last decade, many technical issues for the undulator based positron source have been resolved:
- End to end beam dynamic simulations, including spin tracking by several institutes.
- Constructed and tested a prototype superconducting undulator, total 4 meter long, to the specified field (K=0.92) period (l=1.15 cm). No show stopper identified.
- Calculation on the target heating and shocks from incoming gamma beam shows no major issues identified from the studies.
- A fast spinning target wheel constructed and tested (2000 rpm) at UK with no show stoppers identified.
- Major components such as OMD, normal conducting pre-accelerator are tested to satisfactory.
- A much simplified layout of the remote handling system has been developed, and with much cost reduction from the early design.
- Interfacing with damping ring studied and no issues arisen.

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.

Technical challenge and risk of the baseline target -Vacuum seal

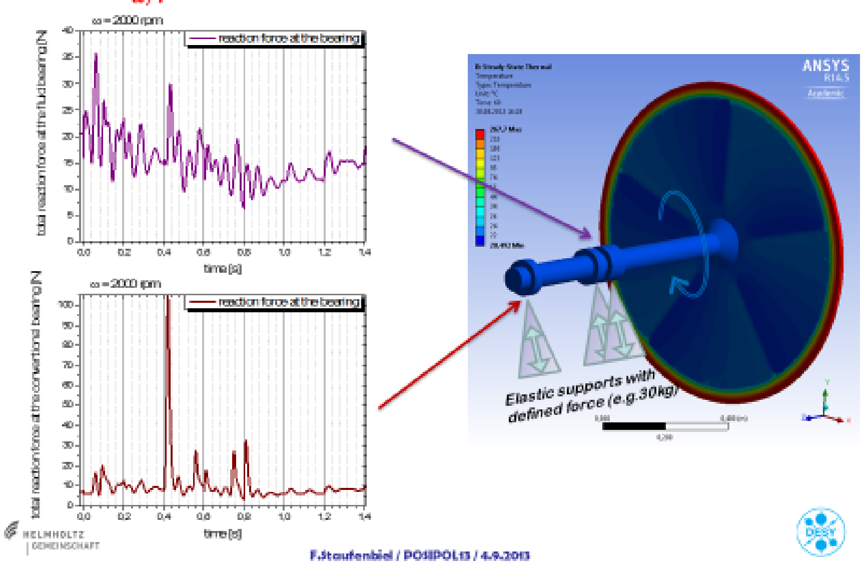


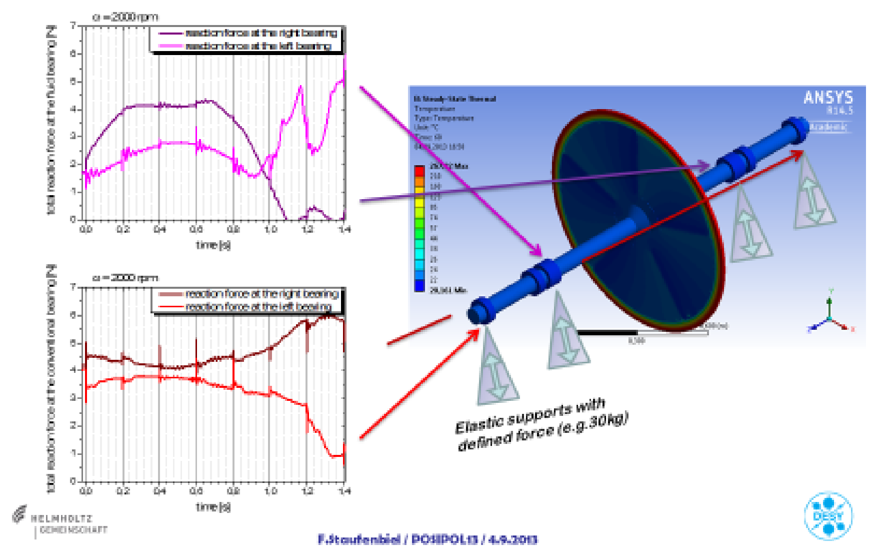
Risks: Test of ferrofluidic seal at LLNL has identified the potential vacuum seal problem of the baseline target system

- Limited life time of a vacuum seal (short time survival, but long term > a few weeks with vacuum spikes) and no further experiments on other type of seal for improved study due to lack of funding.
- No radiation damaging testing yet and cooling water impact on wheel dynamics.

Technical challenge and risk of the baseline target -stress

Dynamical reaction force at the wheel bearings	Dynamical reaction force at the wheel bearings
$\tau = I_{CMS}\underbrace{\alpha}_{a/r} + \omega \times I_{CMS}\,\omega \qquad \omega = 210{,}31\,rad/s\,(2000rpm)$	$\tau = I_{CMS}\underbrace{\alpha}_{a/r} + \omega \times I_{CMS}\,\omega \qquad \omega = 210{,}31\,rad/s\,(2000rpm)$



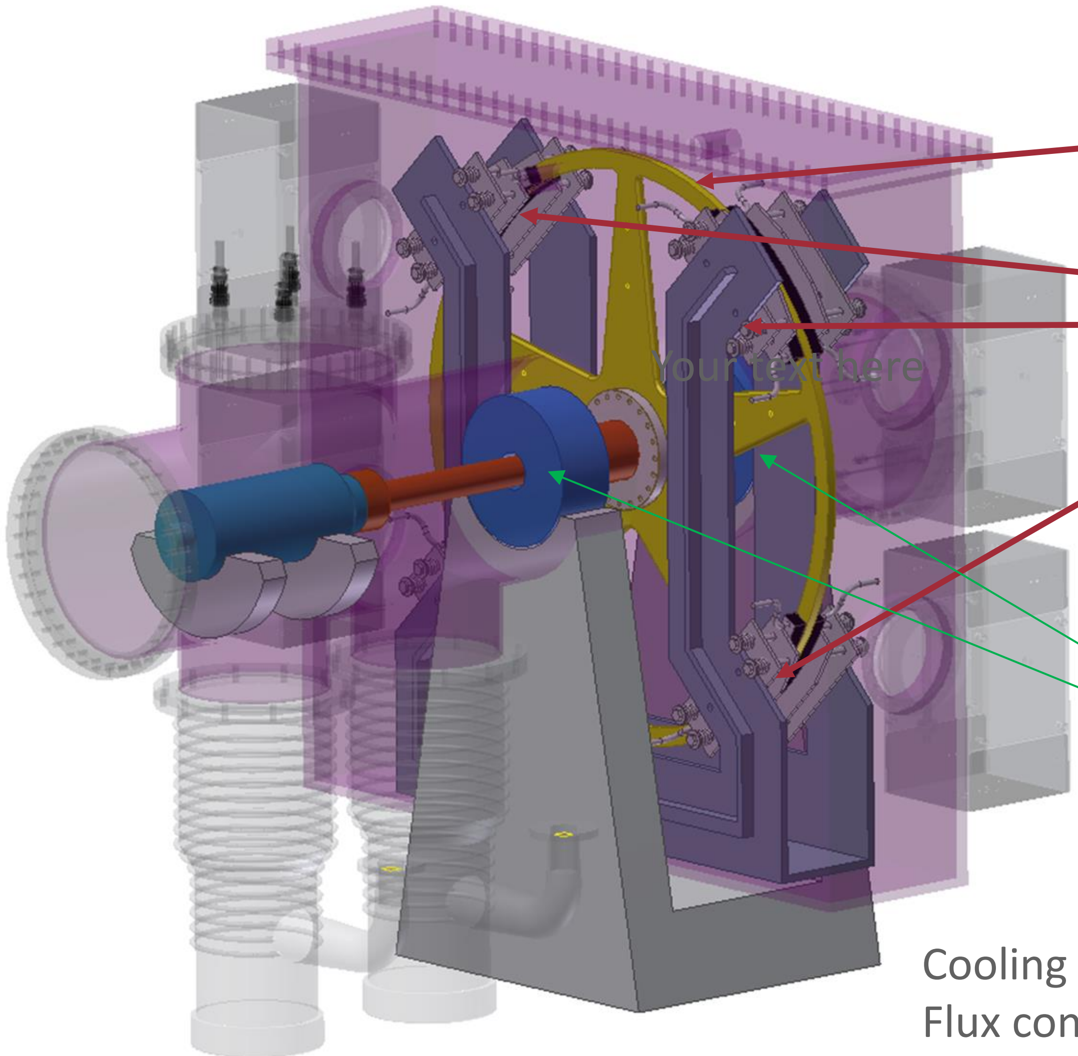


Simulations done by DESY group have identified another potential problem with the wheel support.

An example of a suggested modification version:

- Keys:
  - Eliminate the rotating vacuum seal by putting the whole target system in vacuum chamber.
  - Eliminate the cooling water in any moving parts; heat would be removed by contacting conduction cooling from spring loaded metal pads.
  - Support shaft using the magnetic bearings.

Inside the chamber



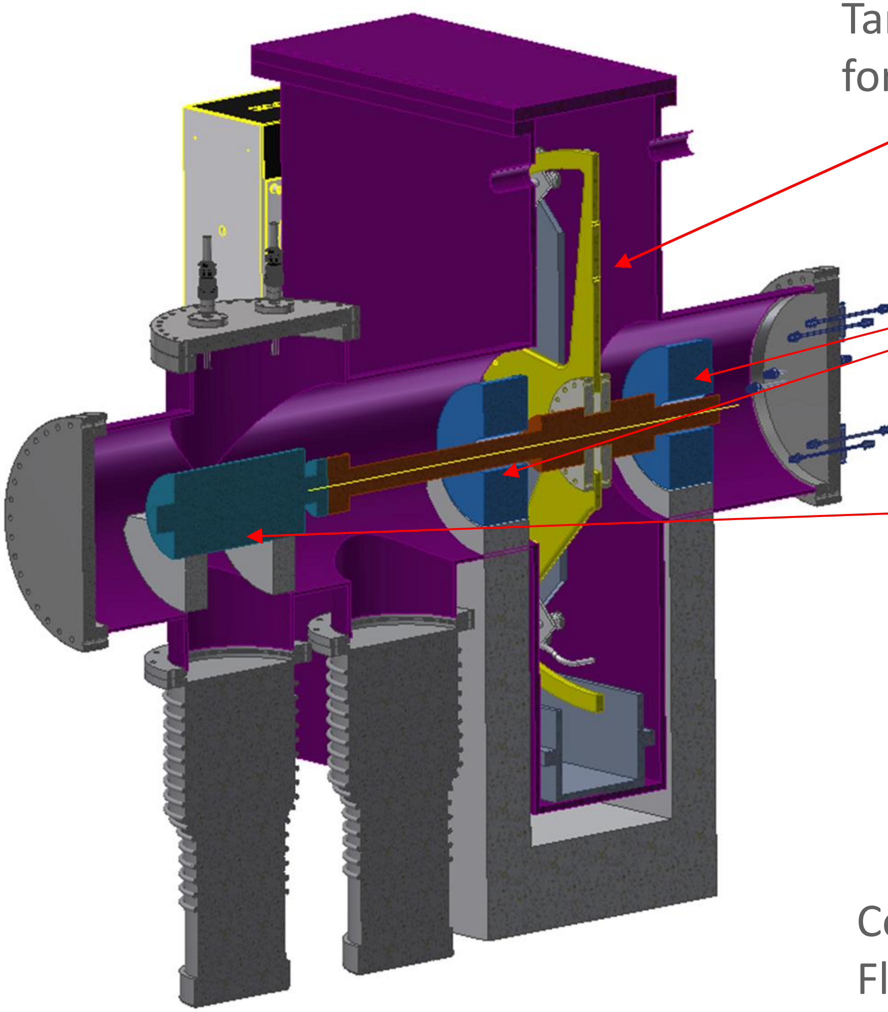
Target wheel, geometry may be optimized for cooling efficiency and wheel balance

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



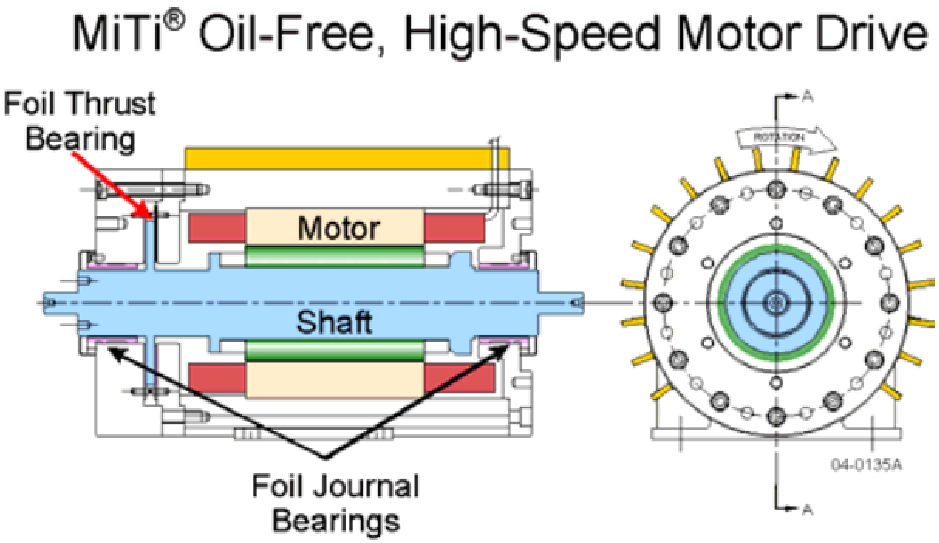
Target wheel, geometry may be optimized for cooling efficiency and wheel balance

Magnetic bearing on both side

Vacuum compatible motor

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

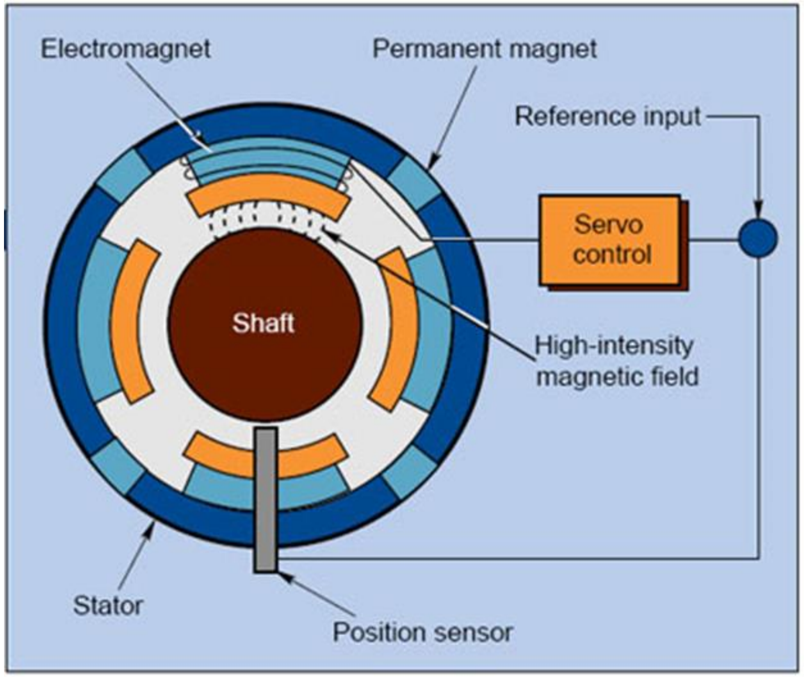
Vacuum compatible electrical motor

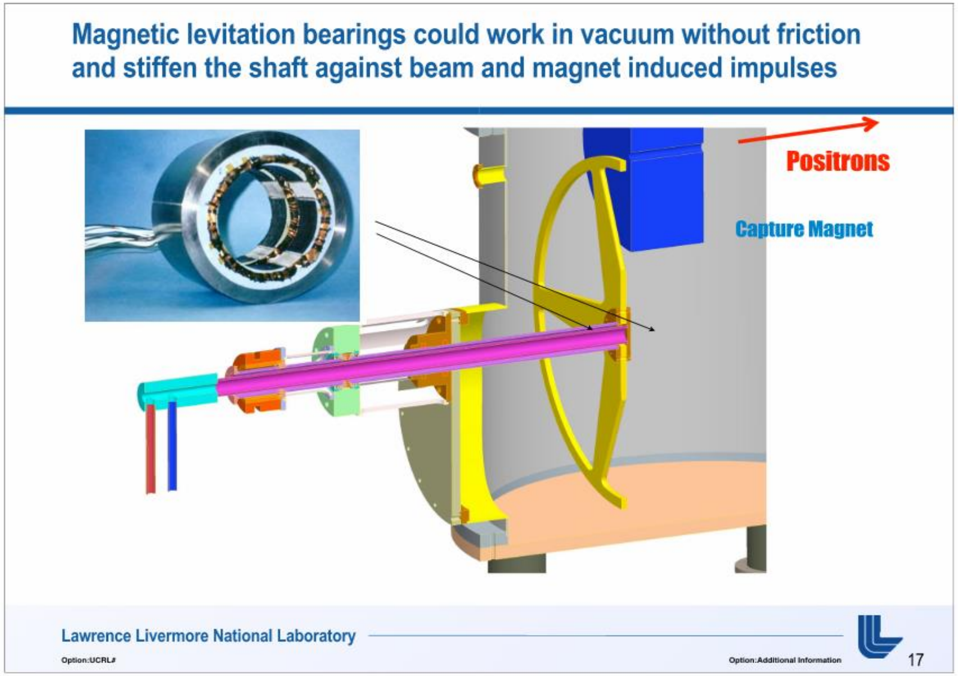


One needs to remember that magnetic motor does not require lubrication itself as long as bearings are lubricated correctly. We consider a motor drive that is oil free and maintenance free.

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.

The friction between target wheel and cooling pad

- The friction between target wheel and cooling pad can be small if vacuum compatible lubricant can be used, example: Tungsten Disulfide (WS_2).
- Tungsten Disulfide (WS_2) or Tungsten Disulphide:
  - 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, so is the pads.
- The contacting area is assumed to be 1/3 of the target wheel with a contact pressure of $1N/cm^2$. 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 pads 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

Thermal resistance test of uncoated copper surface.

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
- Hopefully, we'll have a full featured prototype in 3 years with the contingency of enough resources.