FEL Optics

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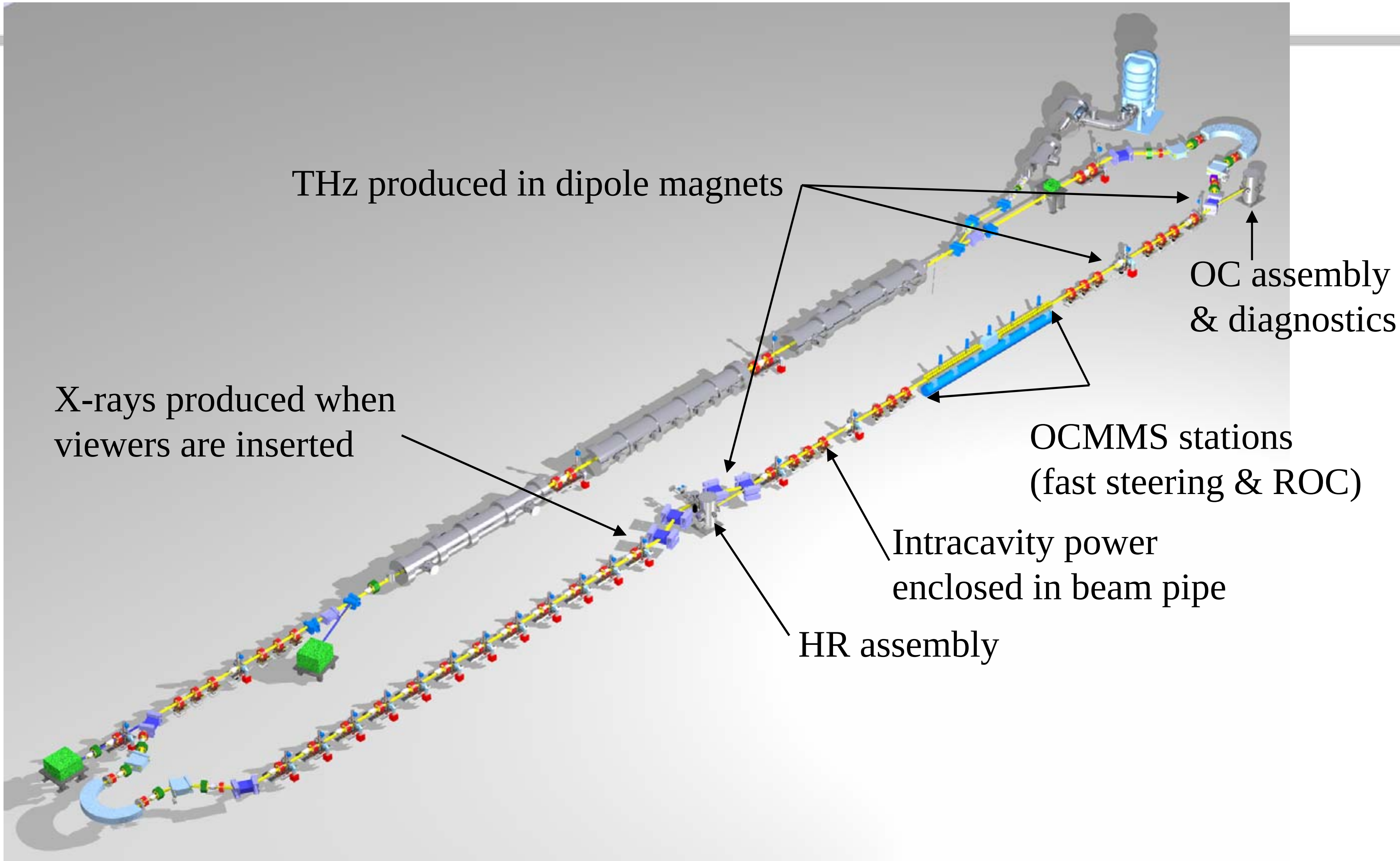
Outline

- Since our last meeting we raised output powers in the 1-3 micron region by ~ 2x.
- In October 2006 we had exceeded 14.2 kW at 1.6 microns.
- How did we do it?
- What have we learned since then
- What future improvements will enhance our capabilities to deliver beam to users.

THE IR UPGRADE OPTICAL CAVITY ENVIRONMENT



OBSERVATIONS

- Once we had sufficiently good performance from the accelerator we found the maximum laser power at sufficiently different wavelengths that we could check the values against predictions.
  - Laser power is linear in beam current - up to a point, then it saturates.
  - A plot of max output power vs wavelength will be linear if the material properties of the substrates (the figure-of-merit) are the same.
- If one then plots the absorbed power as a function of wavelength, this is also linear in wavelength.
- Both results are consistent with analytical models that the power limit is due to absorption in the mirrors and subsequent deformation.
- The question was, why was the absorption so high.

HALF OUR ABSORBED POWER WAS DUE TO THz

- For several years we have used IR (8-12 μm) cameras to observe the cavity mirrors.
  - This summer we used a FLIR Thermovision A20 IR camera to obtain thermographic profiles of the mirrors.
  - We were able to do this while lasing (THz & shorter wavelength radiation) or not lasing (THz only).
  - We found that about half the absorbed power was due to THz, and that diffraction had produced a mode pattern about the size of the laser mode.
  - "THz traps" were installed - this spread out the THz irradiation pattern to cover the mirror.
  - The result: laser efficiency improved.
    - For 1.6 μm, 20% OC: 1.08 kW/mA before traps were installed, 1.4 kW/mA after.

Uncalibrated thermographic image of mirror heating due to THz radiation absorption.

Recorded 4/12/06

THz Traps

CRYOMIRROR DEALT WITH THE REST OF THE LOSS

- 1.6 micron, 20% OC harmonic control coating composed of hafnia/silica multilayers.
  - Lowers intracavity irradiance - and the probability of driving nonlinear processes.
  - Lowers thermal loading on water-cooled, deformable HR mirror.

50K He transfer line

He Distribution & instrumentation

Cryomirror in OC vessel

DISCUSSION

- Redistributing the THz profile and lowering the total mirror load improved the laser efficiency.
- Loss in the mirrors has fallen, the OC mirror (coating + substrate) is below 200 ppm. HR coatings are below 100 ppm. In one case, <30 ppm
- Is the surface loss due to harmonics (either directly or induced) or the fundamental?
- Running for the LIPSS experiment provided a clue.
  - Initial power output was about as expected, 1.2kW (expected 1-3 kW)
  - Power began dropping almost immediately, after ~ 20 hrs of operation, we were down to ~ 300W
  - We had clear signs that there was high loss in both mirrors.
- Operation at 930nm places the 3rd harmonic near the band edge of HfO_2, and the 4th harmonic is at the band edge.
  - This is the highest UV harmonic load we'd subjected our mirrors to, about 2 orders more than the 14 kW run at 1.6 micron.

OUTSIDE RESOURCES ARE WORKING WITH US TO SOLVE THIS ISSUE

- Starting last Summer, ONR gave a modest amount of funding to start a FEL Optics Collaboration.
  - Team includes researchers from China Lake, Colorado State, Univ. of New Mexico, and SAIC.
- The team, which now includes Stanford, successfully submitted a proposal entitled, “Fundamental understanding of optical coatings and novel strategies for power scaling of high power Free Electron Lasers”
  - Provides ~ $2.7M over 5 years.
  - The team is capable of making their own coatings, then do a complete suite of metrology on them.
  - Includes a FEL theorist and provides for testing at JLab.

WHAT DOES THE FUTURE HOLD?

- We are making improvements for more stable performance from the 10 kW Upgrade
  - Improved scattered light control in the optical cavity and optical transport
  - Aperture apodization
  - Radius of control of transmissive outcoupler
  - Optical Cavity Mirror Metrology System (OCMMS) fully implemented.
    - ROC and aberrations monitor and control
    - Fast steering control
  - Cryocooling all OC mirrors
- Begin replacing “OTS Lite” components with “OTS Standard” versions.
  - These are designed for high power (+10 kW) beam delivery
- Add beam delivery to two more user labs (3 & 5)
- We will validate the 100 kW mirror and optical system criteria in continuing oscillator tests.

Some of the JLab Team

Photo taken Jan 16, 2007

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