


Proton Radiation Testing of Laser Optical Components for NASA Jupiter Europa Orbiter Mission



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Overview

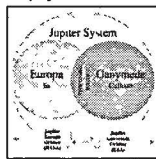
- EJSM Mission and Europa
- Proton Testing at Indiana University Cyclotron Facility (IUCF)
- Samples Tested
- Results
- Visual Inspection
- Conclusions

Europa Jupiter Science Mission (EJSM)





- NASA and ESA: Shared mission leadership
- Independently launched and operated orbiters
 - NASA-led Jupiter Europa Orbiter (JEO)
 - ESA-led Jupiter Ganymede Orbiter (JGO)
- Complementary science and payloads
 - JEO concentrates on Europa and Io
 - JGO concentrates on Ganymede and Callisto
 - Synergistic overlap
 - 11-12 instruments each
- Science goals:
 - Icy world habitability
 - Jupiter system processes



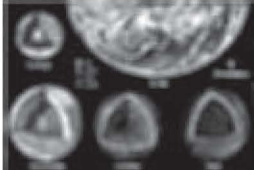
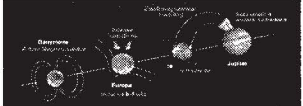
Synergistic science: The sum of JEO + JGO is greater than the parts

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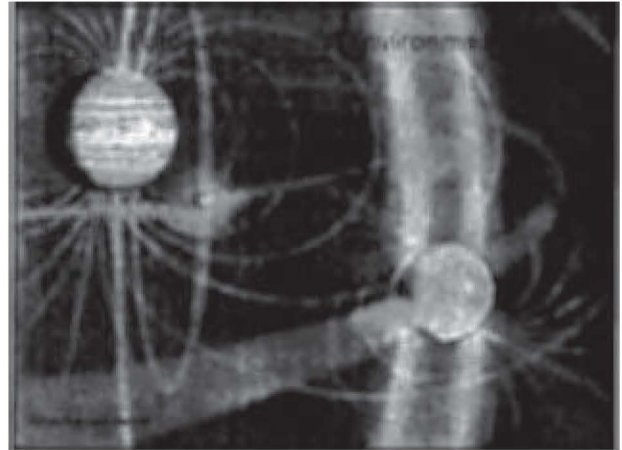
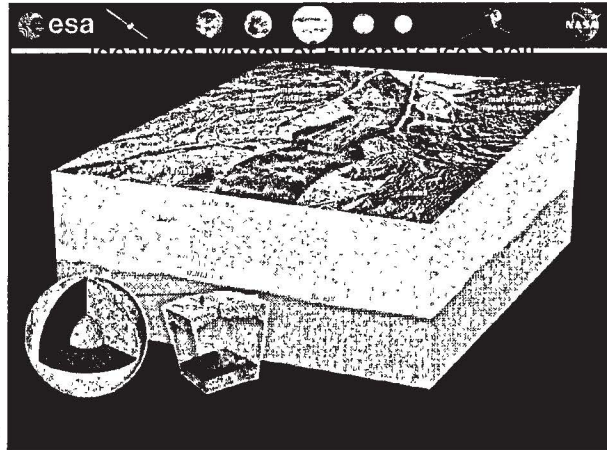
EJSM Theme: The Emergence of Habitable Worlds Around Gas Giants

- **Goal 1:** Determine if the Jupiter system harbors habitable worlds
 - Ocean characteristics
 - Ice shells and subsurface water
 - Deep internal structure, and (for Ganymede) intrinsic magnetic field
 - External environments
 - Global surface compositions
 - Surface features and future landing sites
- **Goal 2:** Characterize Jupiter system processes
 - Satellite system
 - Jupiter atmosphere
 - Magnetodisk/magnetosphere
 - Jovian system Interactions
 - Jovian system origin

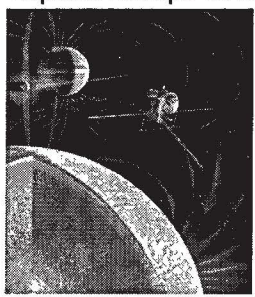
Emphasis on icy moon habitability and Jupiter system processes

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JEO Goal:
Explore Europa to Investigate Its Habitability



Habitability Objectives (prioritized):

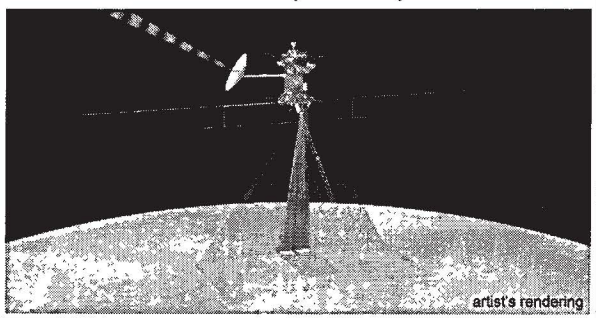
- Ocean and Interior
- Ice Shell
- Chemistry and Composition
- Geology and Landing Sites
- Jupiter System
 - Satellite surfaces and interiors
 - Satellite atmospheres
 - Plasma and magnetospheres
 - Jupiter atmosphere
 - Rings

Characterizing the archetype of icy world habitability

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Orbital Operability



Multiple optical systems being considered for inclusion on JEO

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JEO Radiation Environment



- Four major sources of radiation
 - Solar energetic particles during interplanetary cruise (protons, electrons, and heavy ions)
 - Galactic cosmic rays during interplanetary cruise (protons and heavy ions)
 - Trapped particles in Jovian magnetosphere during Jovian tour and orbits of Europa (electrons, protons, and heavy ions)
 - Particles from onboard nuclear power source (neutrons and gammas)
- The high-energy trapped electrons and protons are dominating contributors to Total Ionizing Dose (TID) and Displacement Damage Dose (DDD)
- Expected radiation dose is 2.9 Mrad (Si) behind 100 mil Al
- Proton testing chosen as an initial screening

Optical Components for Proton Testing



Component	Designation	Material
Crystalline Laser Rod	NE YAG	Neodymium-doped yttrium aluminum garnet
	1064 nm bandpass filter	Bandpass filter
Filter	532 nm bandpass filter	Bandpass filter
	KDP Q-switch	Potassium di-deuterium phosphate Q-switch
Polycrystalline (ceramic) Laser Rod Materials	1%Nd YAG	Neodymium-doped yttrium aluminum garnet
	1%Nd 0.5%Cr YAG	Neodymium-chromium co-doped yttrium aluminum garnet
	1%Nd 0.5%Ce YAG	Neodymium-cerium co-doped yttrium aluminum garnet
	20%Yb YAG	Ytterbium-doped yttrium aluminum garnet
	20%Yb 0.5%Cr YAG	Ytterbium-chromium co-doped yttrium aluminum garnet
	20%Yb 0.5%Ce YAG	Ytterbium-cerium co-doped yttrium aluminum garnet
	1%Nd YVO ₄	Neodymium-doped yttrium orthovanadate

IUCF Proton Test Setup

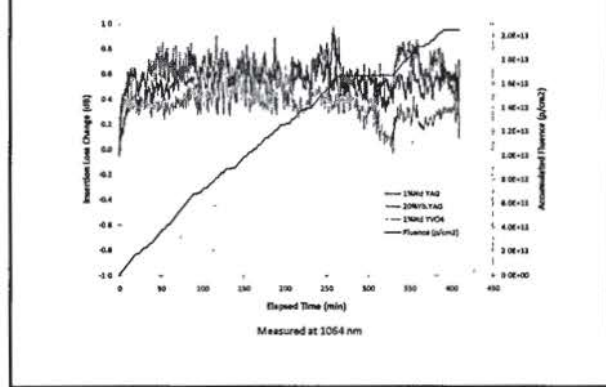


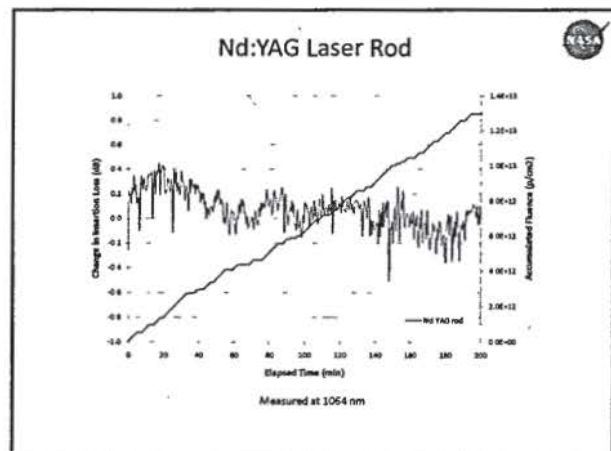
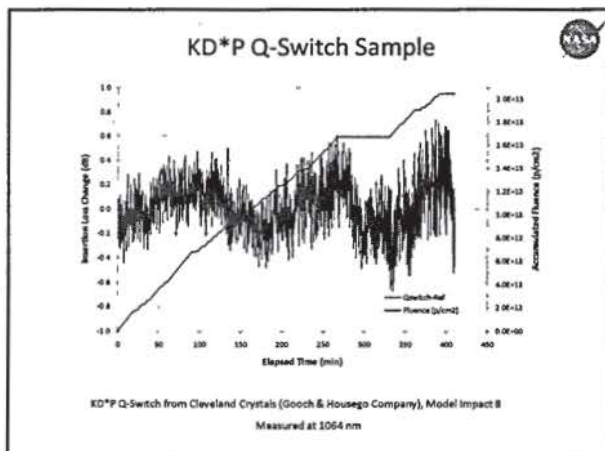
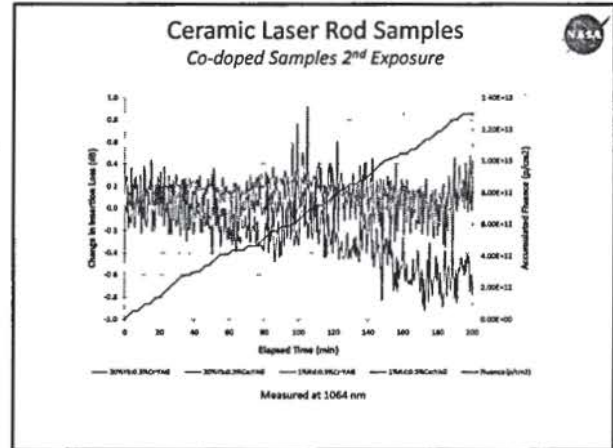
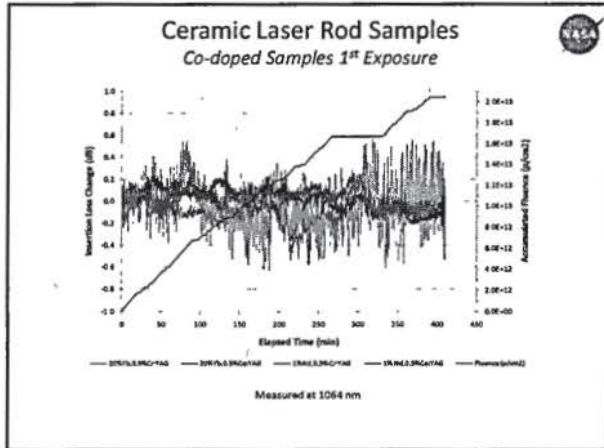
Beam Current = 50 nA
4 cm thick Copper Block
1.5-1.7 x 10¹⁶ p/cm²/sec
0.23-0.26 krad/sec

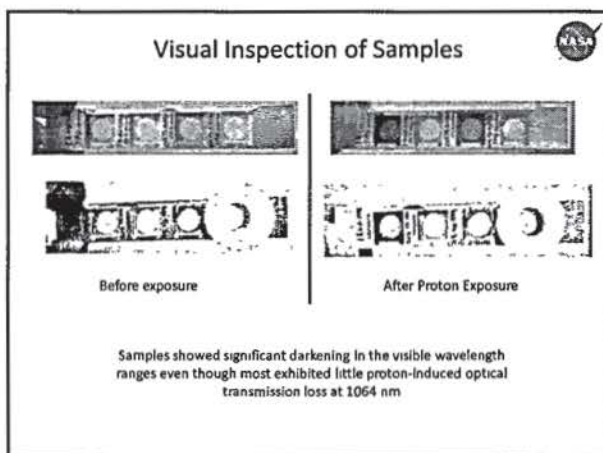
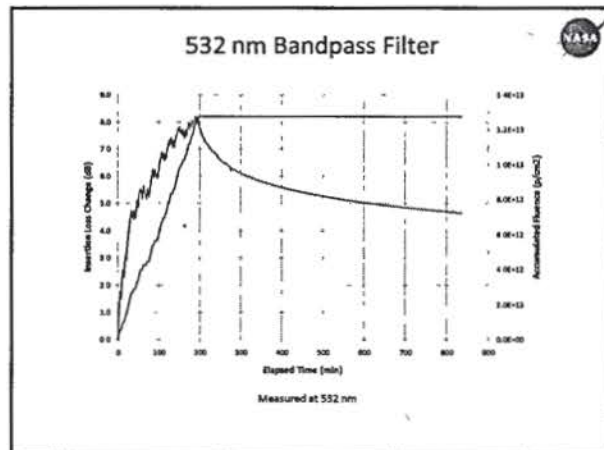
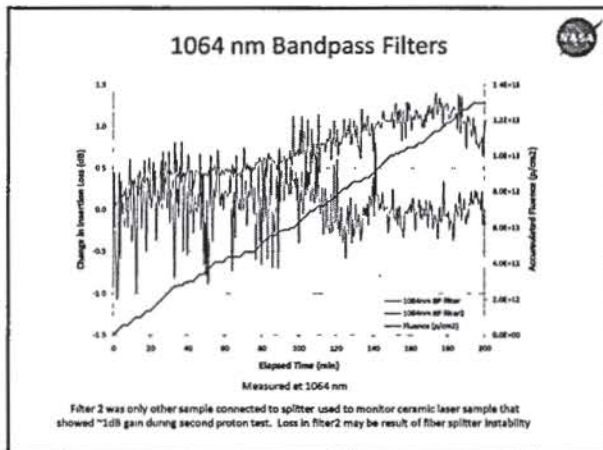
Data Acquisition Room

Proton Test Cell (RERP2)

Ceramic Laser Rod Samples







Conclusions

- Several standard laser materials and some polycrystalline (ceramic) laser materials irradiated at proton fluences in the $1-2 \times 10^{13}$ p/cm² range (2-3 Mrad)
 - Co-doped ceramic samples showed no significant darkening
 - Single-doped ceramic samples showed initial loss of 0.4-0/6 dB, which stabilized for remainder of test
 - Nd:YAG and KD*P Q-switch showed no significant darkening
- Most materials exhibited photodarkening at visible wavelengths
 - 532 nm bandpass filter showed large 8 dB loss during proton exposure

For additional information please see our website
<http://photonics.gsfc.nasa.gov>