Risk Assessment Method for Back-Reflections from Space Debris in High-Power Laser Ranging

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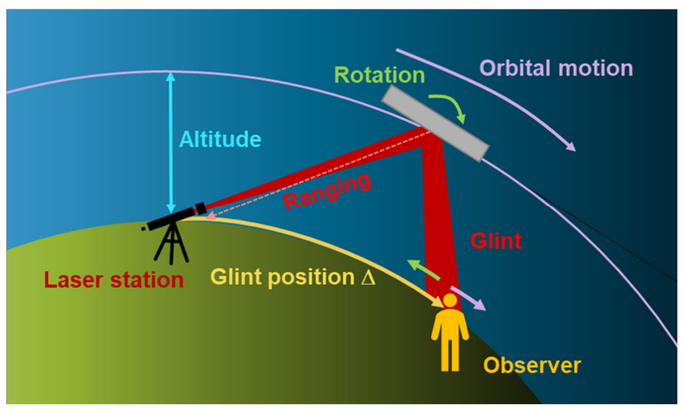
Laser exposure from orbit?

Assumptions

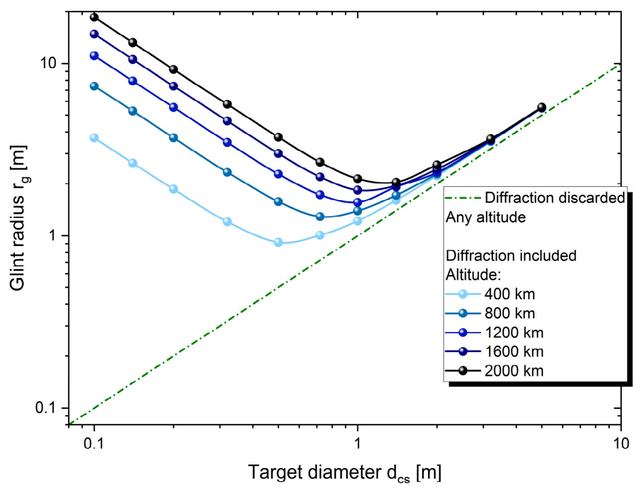
- Specular reflection (worst case)
- Flat target geometry
- 2D irradiation scene



Unintended laser exposure of a remote observer by specular reflection ("laser glint") from space debris.

Glint radius

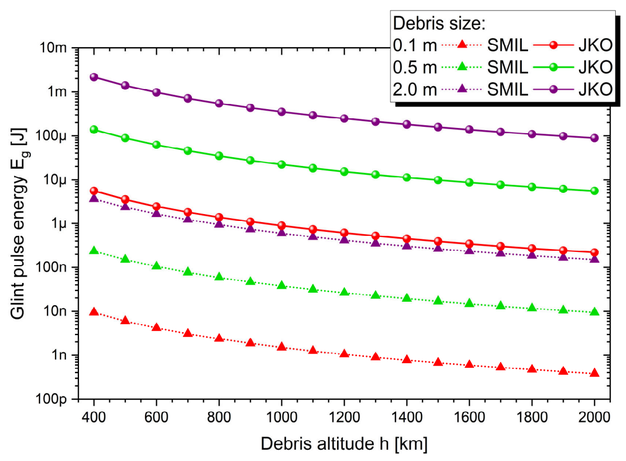
- Gaussian beam propagation
- Beam broadening by turbulence
- Diffraction from target outshining



Glint radius for nadir-pointing back-reflection from debris, irradiated at the zenith of a laser ranging station.

Glint energy

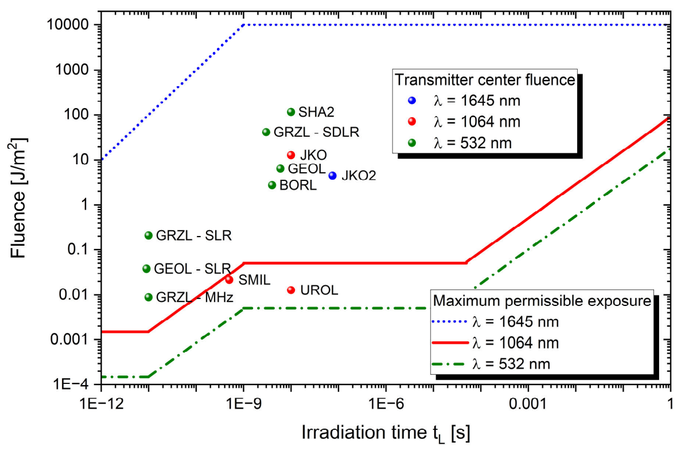
- Atmospheric attenuation
- Target outshining losses



Reflected energy from a debris object at station zenith. Laser pulse energies: 85 µJ (SMIL) and 50 mJ (JKO), resp.

Maximum permissible exposure (MPE)

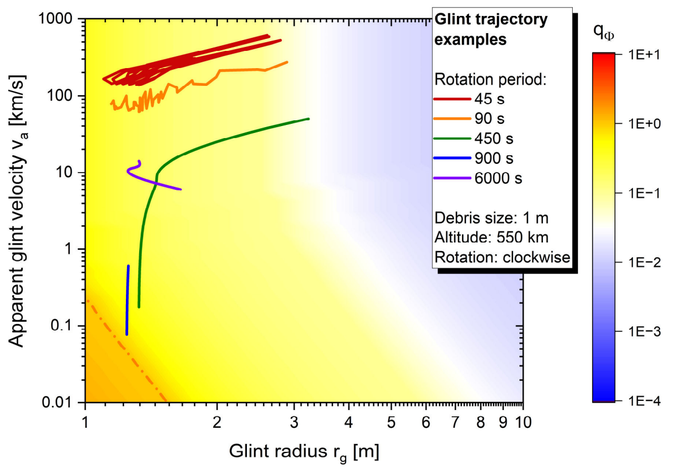
- EU legislation: Directive 2006/25/EC
- Limits for single and multiple pulses
- Excess factor: q_Φ = *Fluence/MPE*



EU MPE limits for the human eye for different laser wavelengths and irradiation times. Symbols indicate the laser fluence at the transmitter center of different stations for satellite (SLR) and space debris (SDLR) laser ranging.

System-specific MPE excess chart

- Fluence → glint energy, size
- Number of pulses → velocity



(top) DLR laser ranging station JKO (Johannes-Kepler Observatory) in Empfingen, Germany.
(bottom) System-specific MPE excess chart (IR-A, 50 mJ) with examplary glint trajectories (Energies: 50 - 300 µJ).

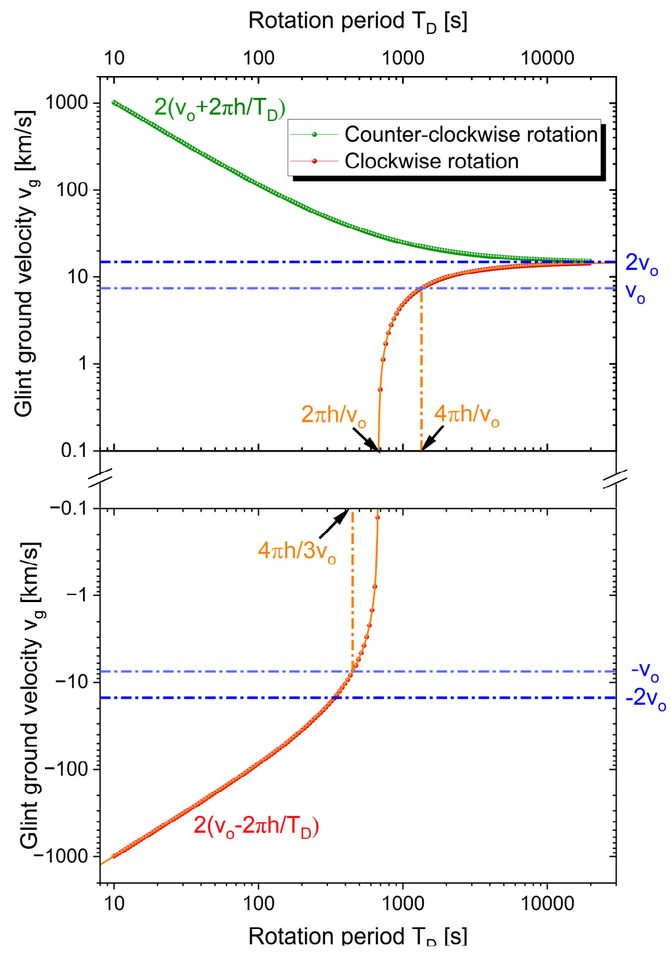
MPE excess chart usage

- Orbit + rotation data + raytracing → Glint motion, size & energy
- Downscaling of q_Φ by E_g/E_L

Glint velocity

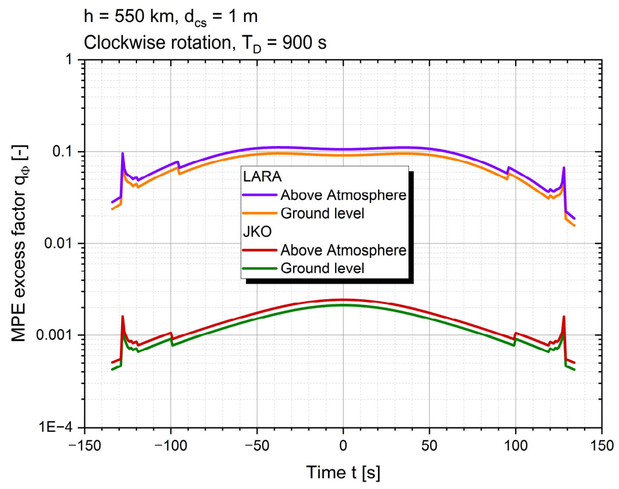
- Glint motion strongly affected by target motion
- Fast glint motion for CCW rotation
- Slow motion for slow CW rotation

→ multiple-pulse irradiation



Glint velocity for laser pointing to zenith and back-reflection in nadir direction from 800 km altitude. v_0 denotes the corresponding orbital velocity.

Dynamic risk assessment



Temporal course of the MPE excess factor for an examplary space debris ranging measurement. LARA station: focused laser beam, turbulence-compensated.

Summary

- Crucial role of debris rotation
- Laser ranging: often below MPE
- Essential for high-power laser momentum transfer (LMT)