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Space debris problem and possible methods for its solution

21st International Workshop on Laser Ranging

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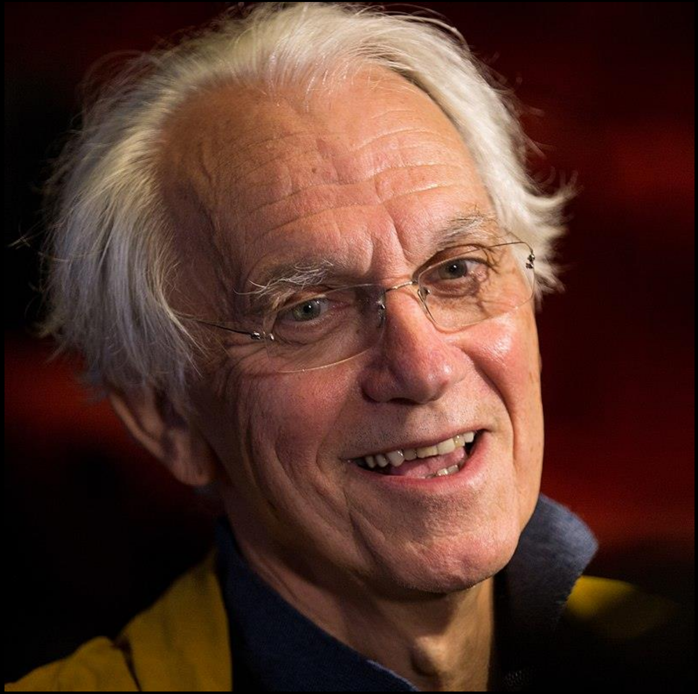
Apologies



I am not Prof. Mourou, sorry.

He wants to come here, but couldn't, because of “unexpected event”.

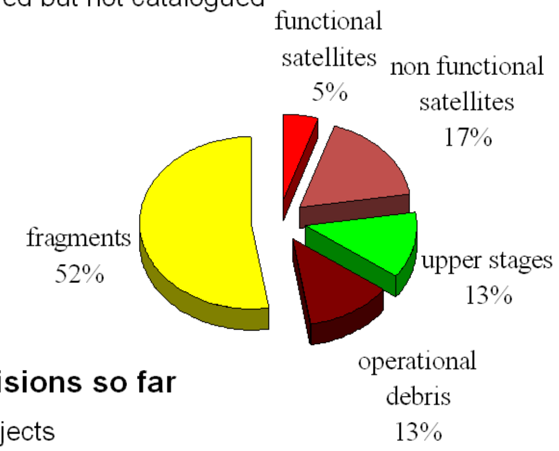
He asked me to present his talk instead of him.

SPACE DEBRIS DISTRIBUTION

NUMBER OF OBJECTS IN ORBIT

Roughly 23,000 large objects in space:

- **17,200 catalogued objects (> 10 cm)**
  - roughly 6,000 additional objects, identified but not catalogued
- **720,000 debris larger than 1 cm**
- **135 million debris larger than 1 mm**



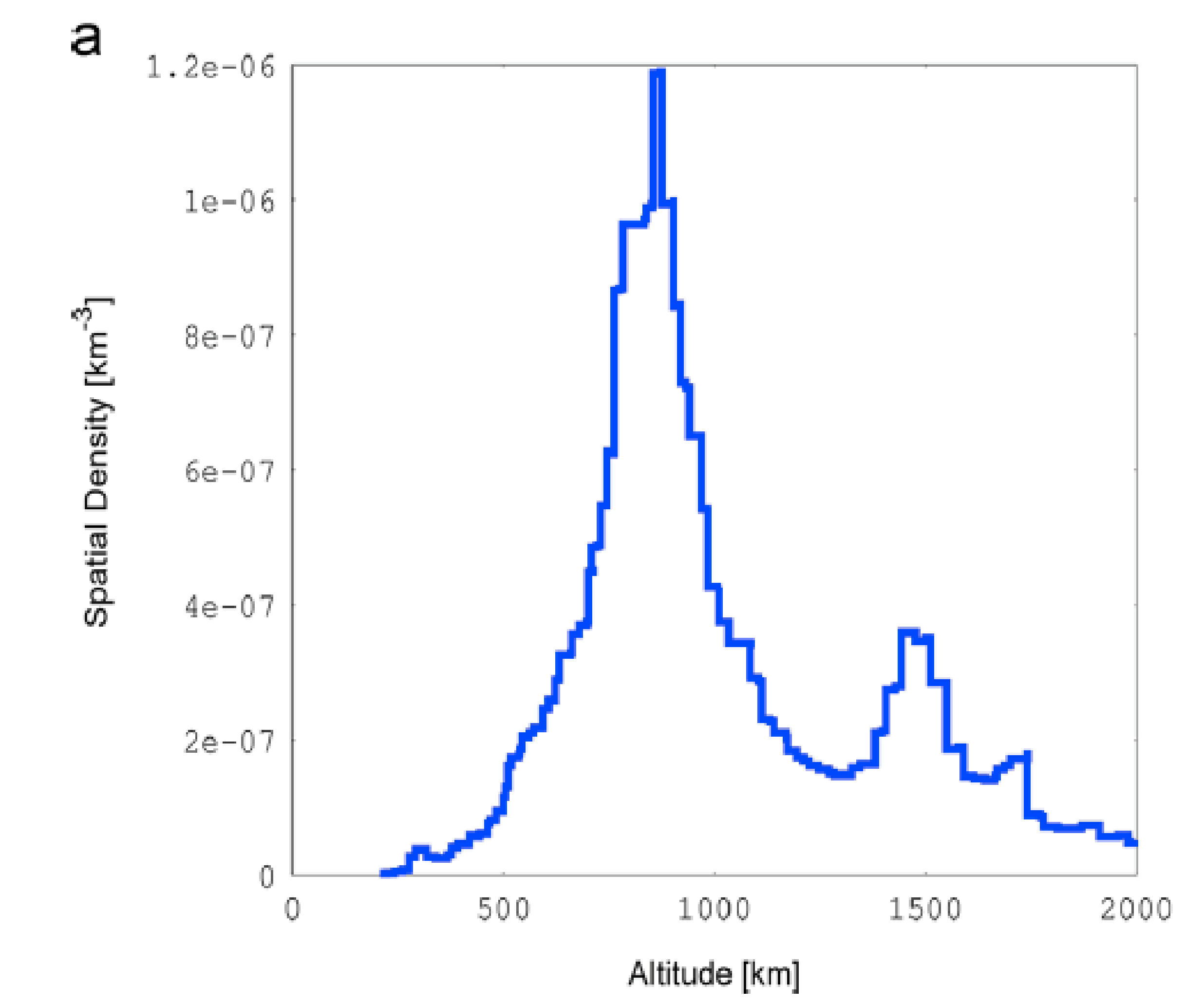
But orbital debris density is very low:

- **Very limited number of registered collisions so far**

  5 official collisions between catalogued objects

  64 suspected with smaller debris

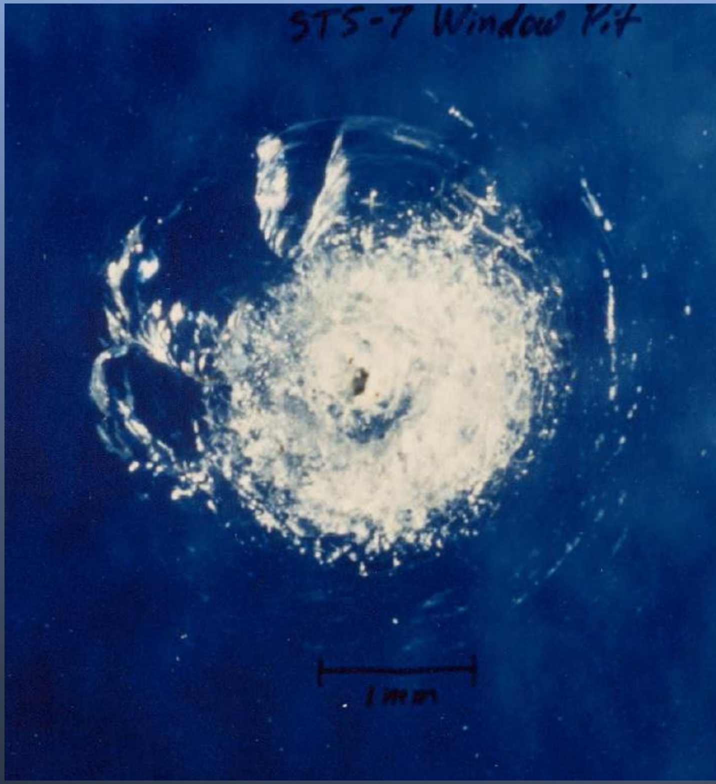
SPACE DEBRIS DISTRIBUTION



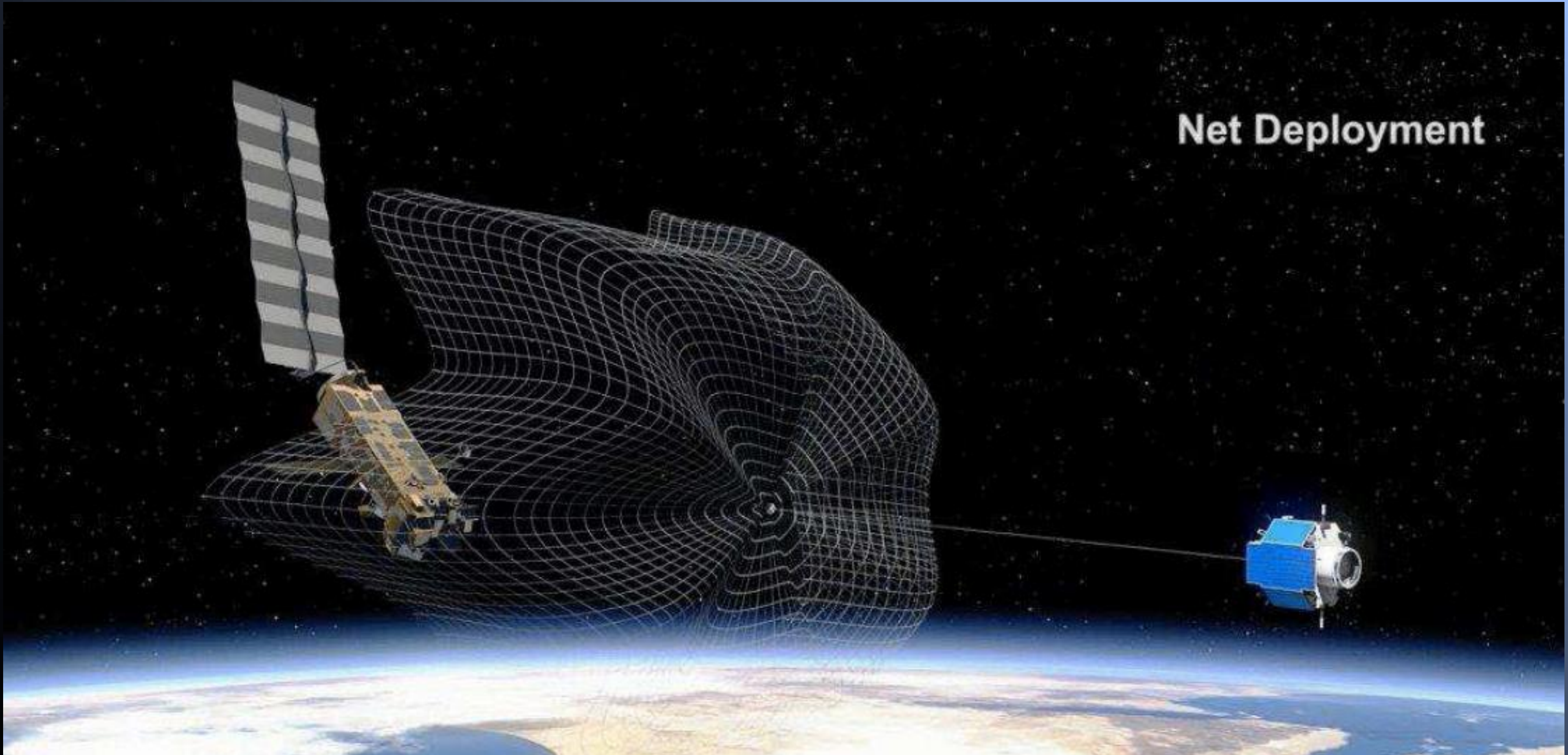
Feng-yung

-Cosmos-Iridiur

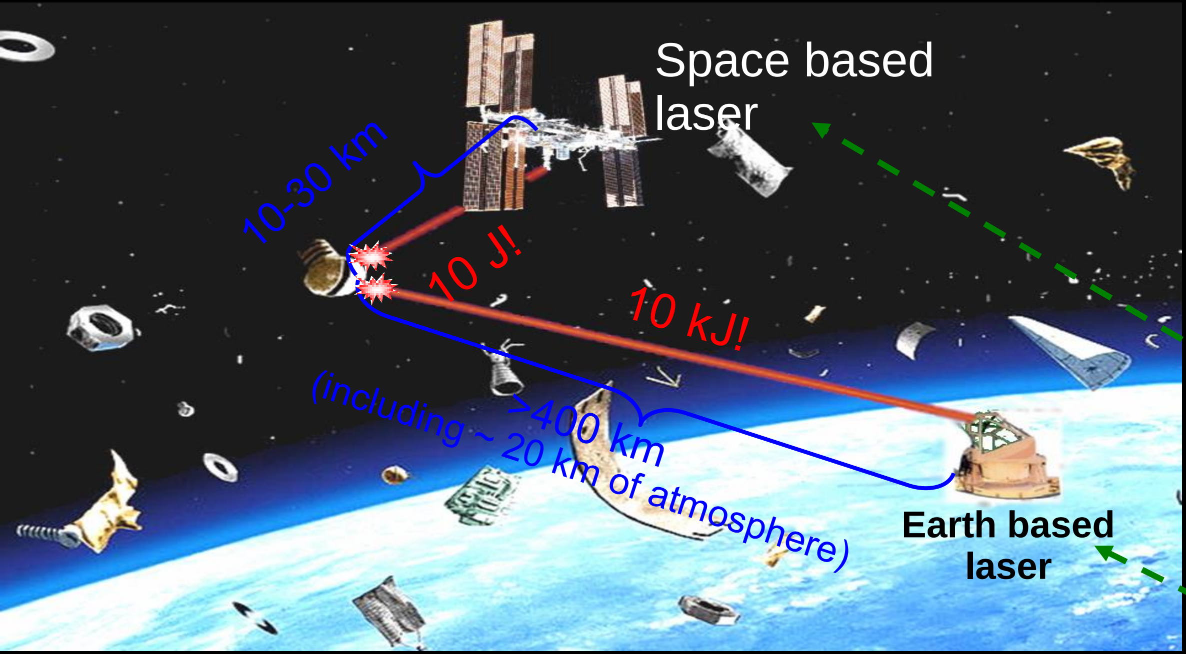
SPACE DEBRIS: Range from Meter to submm -



Strategy for Space Cleaning Challenge: Gros Debris



De-orbiting by space based laser



Short distance

Absence of atmospheric distortions

Ps pulse duration for ablation

[*Ebisuzaki, T., et al., Demonstration designs for the remediation of space debris from the International Space Station. Acta Astronautica, 2015. 112: p. 102–113*]

[Phipps, C. and H. Friedman, *ORION: clearing near-Earth space debris using a 20-kW, 530-nm Earth-based, repetitively pulsed laser.* Laser]

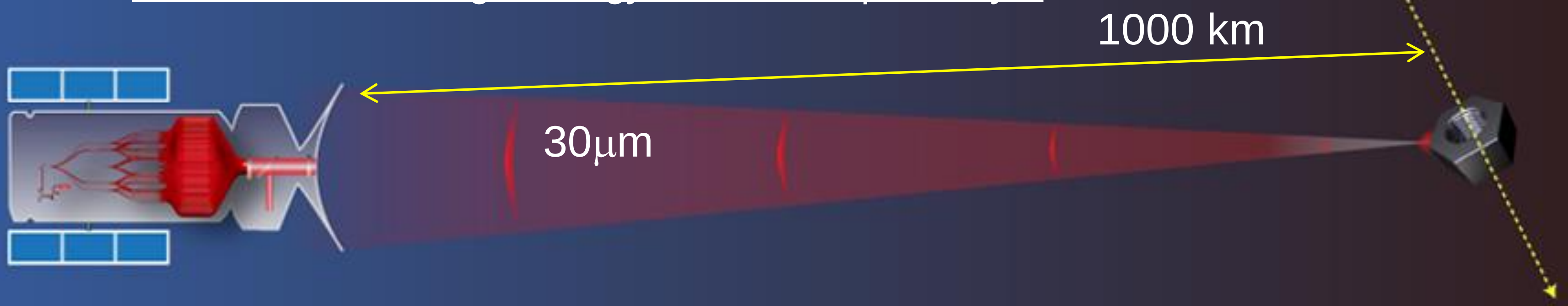
Only few Joules at ~ kHz rep rate is enough for the de-orbiting of small scale (up to 10 cm in size) space debris

G.Mourou et al (2013 ?): ICAN laser for space debris removal

Precise Orbital Debris Parameters: High Energy-Ultra short Pulses

Why High Energy and Short Pulse ?

How to solve the High Energy Short Puls quandary ?



1 High energy and short pulse for precision ranging <<1mm over long distance (1000km) 10^9/ 1

2. Precision measuring Shape with Sub mm precision

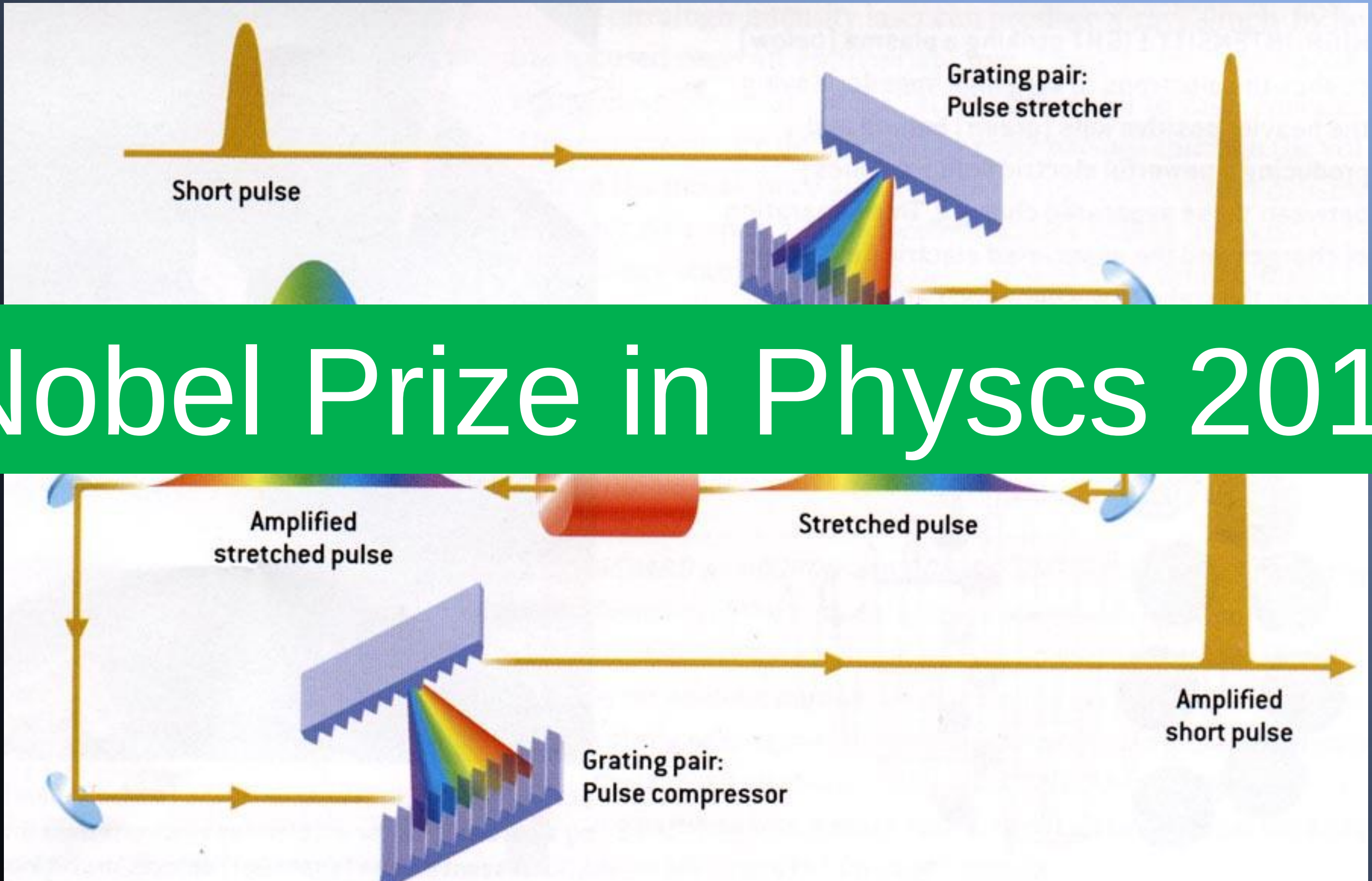
3. Very high peak power for laser-induced breakdown and plasma ejection.

   a. deorbiting by rocket effect

   b. elemental analysis for material identification

Solving the Energy-Short Pulse Quandary (CPA)

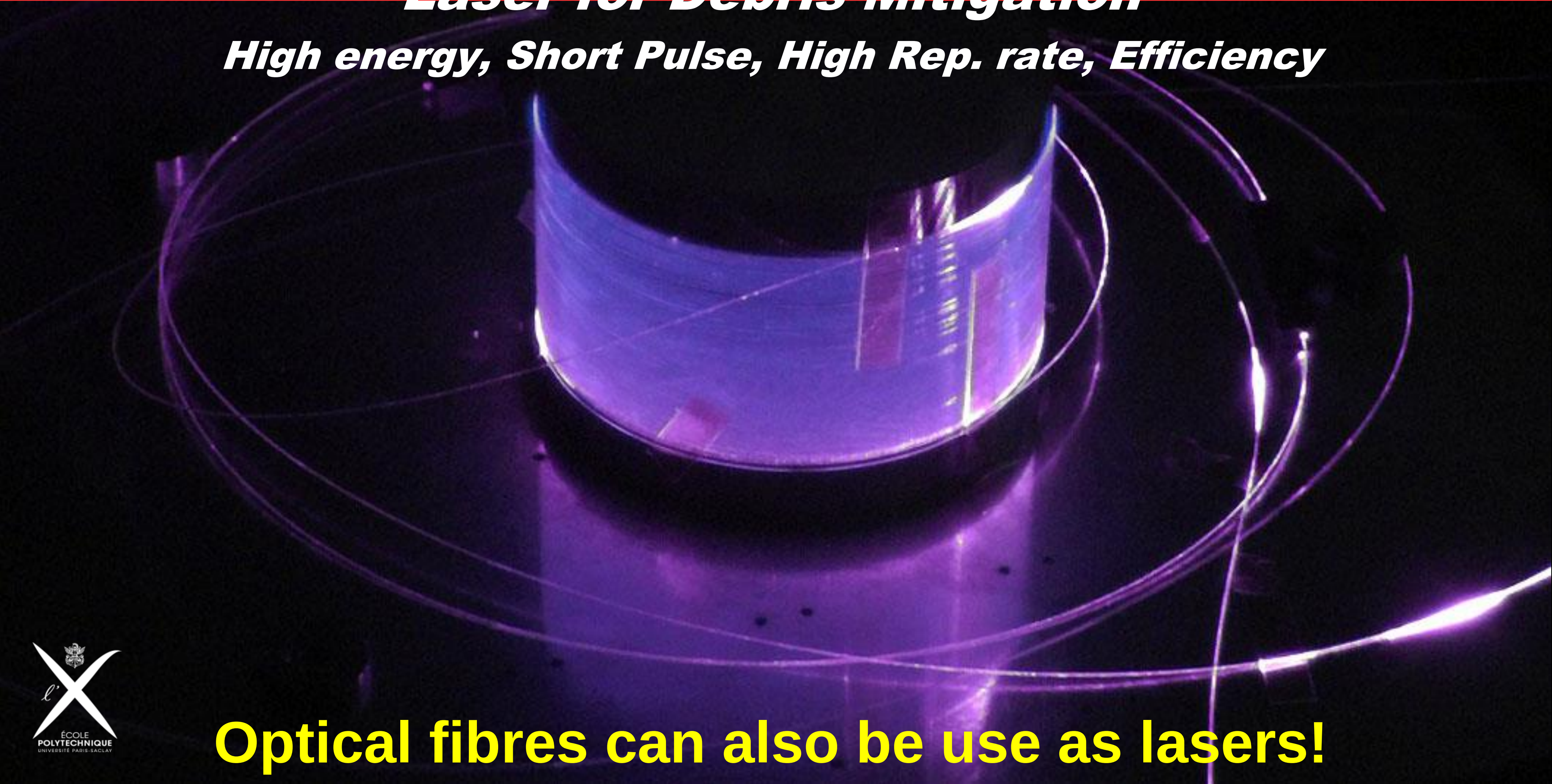
G.Mourou D. Strickland (1985)



Nobel Prize in Physcs 2018

Laser for Debris Mitigation

High energy, Short Pulse, High Rep. rate, Efficiency



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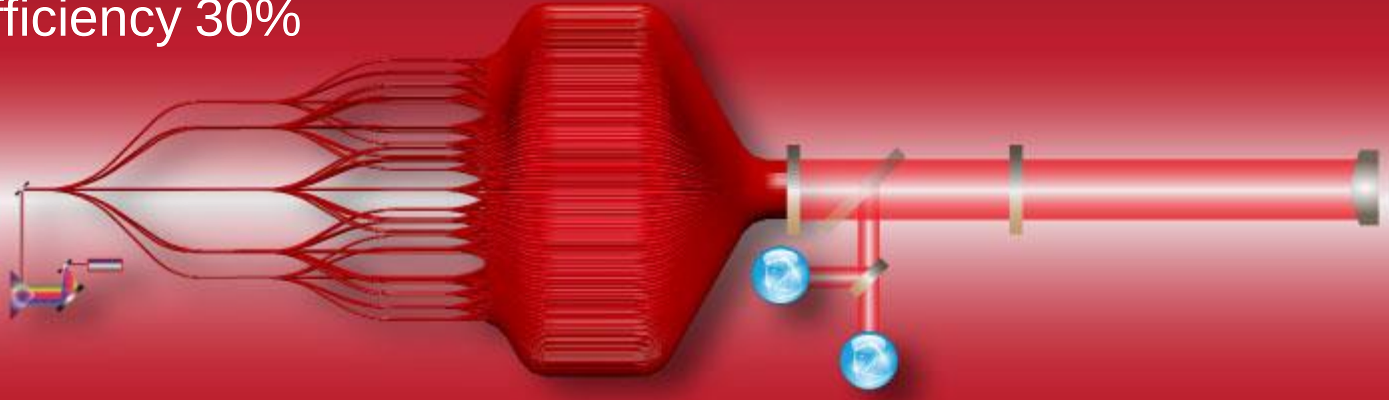
Optical fibres can also be use as lasers!

SPACE ***DEBRIS*** ***- A state of emergency!***

Seeking a laser with:
Short Pulse 100fs
High energy Joules
High Repetition (high rep.rate) :kHz
High efficiency 30%



Starts with a single fibre laser
Fibre is spliced into 10,000 fibres

XCAN *– X Coherent Amplification Network*

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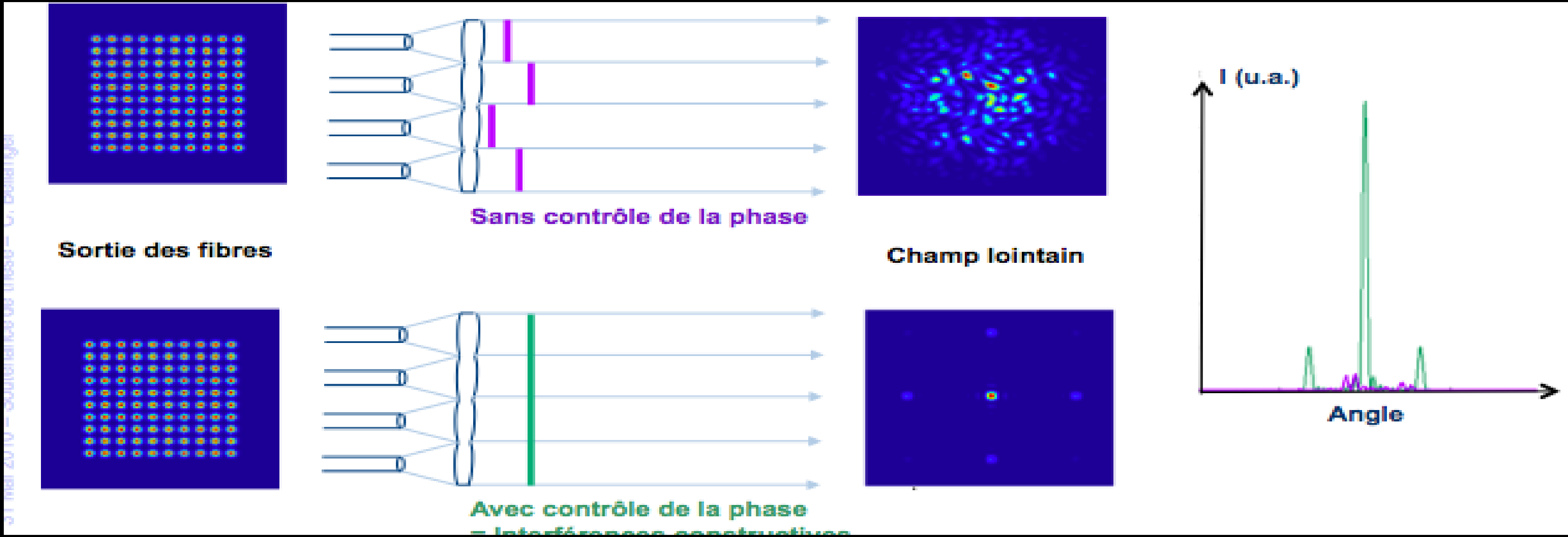
64 CW fibers have been phased

(This experiment in fact validates an extension possible to $>10^4$ phased fibers at 1kHz)

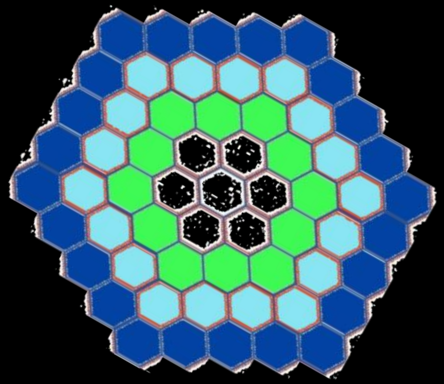


61 channels

350 fs

>10 mJ

50 kHz

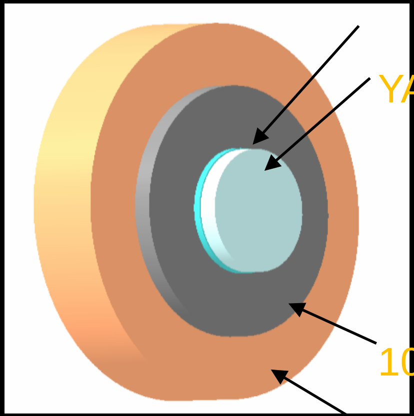


Alternative approach based on a disk laser

Main ideas for space based disk laser are

composite active element → simpler optical scheme

reduced duty cycle pumping → passive cooling of AE and pumping diodes



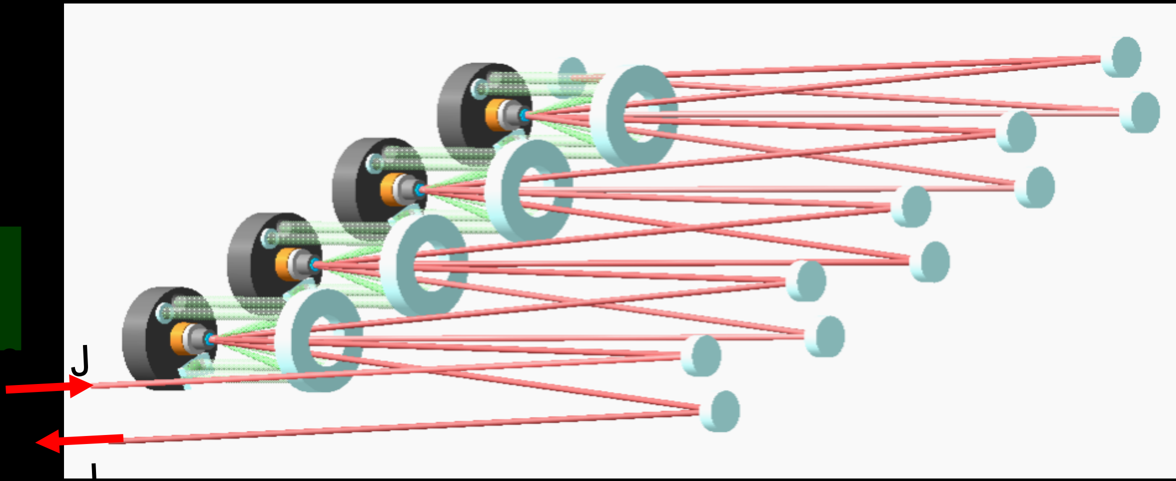
Yb:YAG (D = 50 mm, h = 0.5 mm)

YAG (D = 50 mm, h = 3 mm)

75 kW peak power pump (0.2ms/500Hz)

100 mm CVD-diamond

Passively cooled heat exchanger



All components (including pump modules are available)

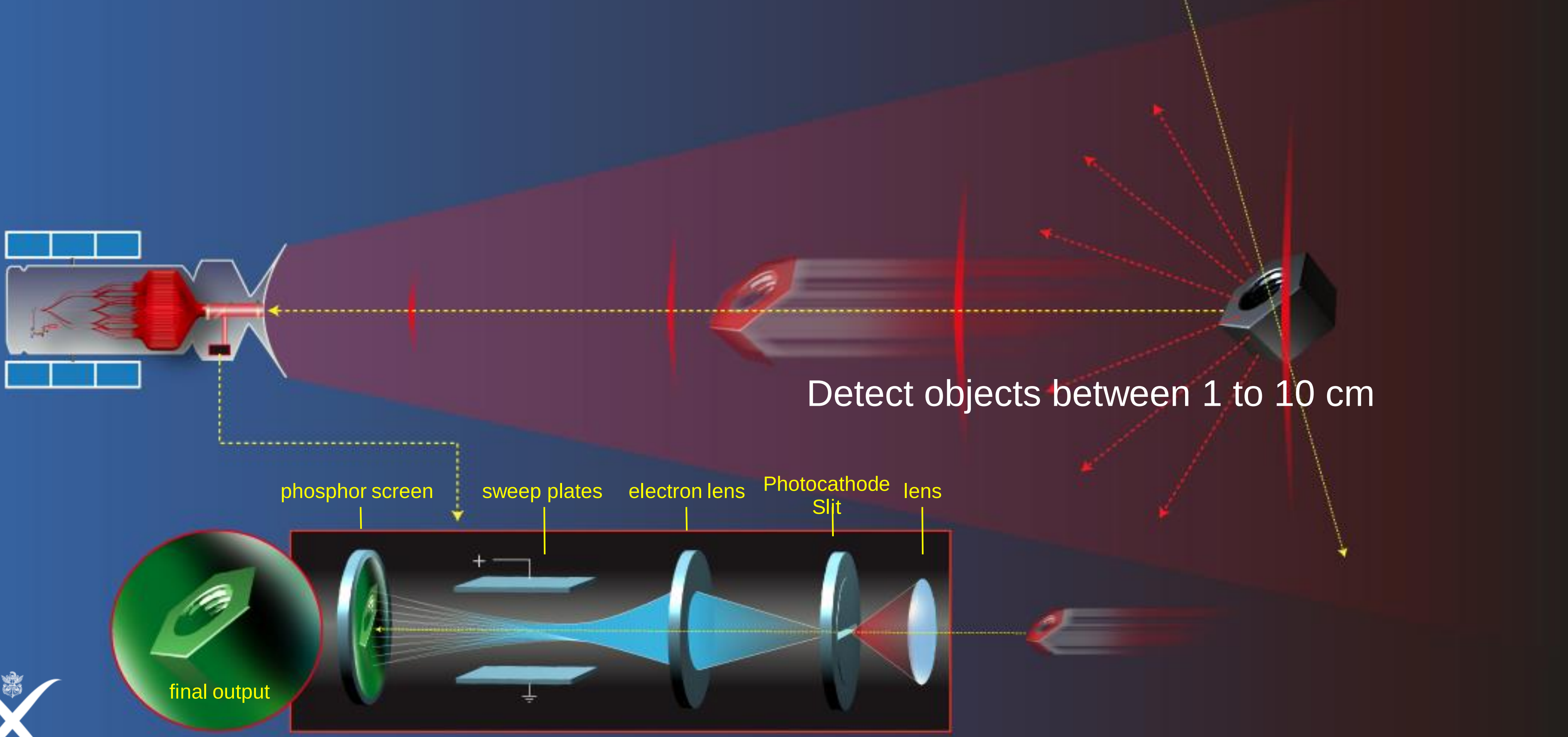
Burst mode regime is more attractive from the pint of view of thermal task in AE

4 Laser heads in multipass scheme will be enough for high gain amplifier

CPA-free amplification is possible for ~100 ps pulses

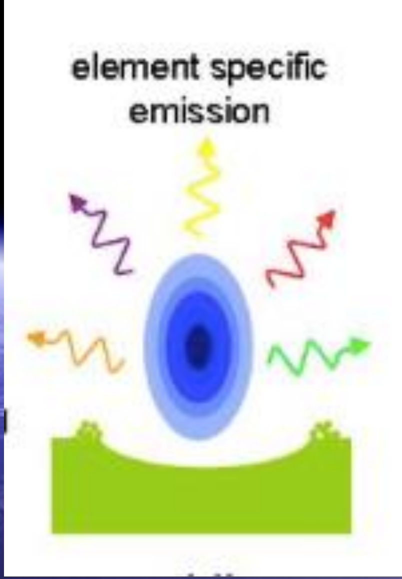
but, a lot of adjustable optics will lead to weak point-to-p

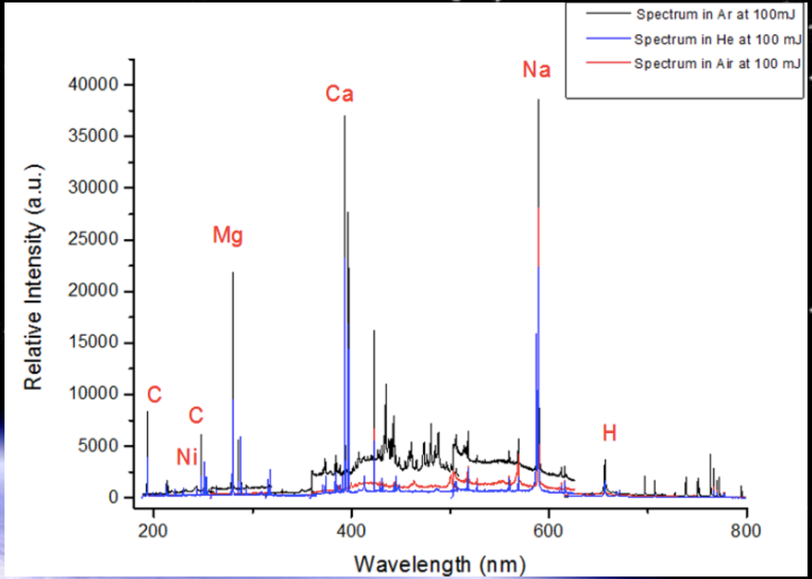
Measuring Ephemerids with very high precision (10^{9}/ 1)



Streak camera Ultrafast Detector

Debris identification: Laser Induced Breakdown Spectroscopy



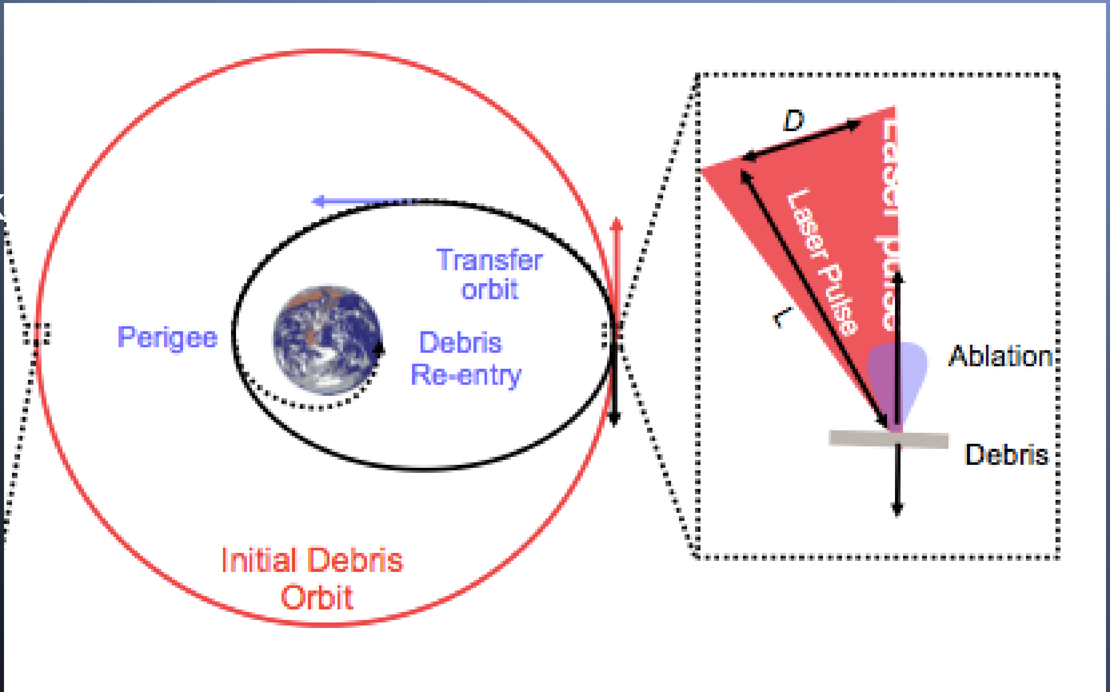


Ultrashort Laser-Deorbiting Concept

C.Phipps, C. Bonnal Acta Astronautica118, P224(2016)
T. Ebisuzaki et al. Acta astronautica .112, 102 (2015)

The laser provides the means to deliver a brief recoil impulse by ablating a thin surface layer on the debris. As shown in Figure.
The ablated material forms a jet normal to the surface which induces a recoil in the opposite direction slowing the debris by v.

Click



EUSO + XCAN = Debris sweeper

Additional Module on ISS for XCAN

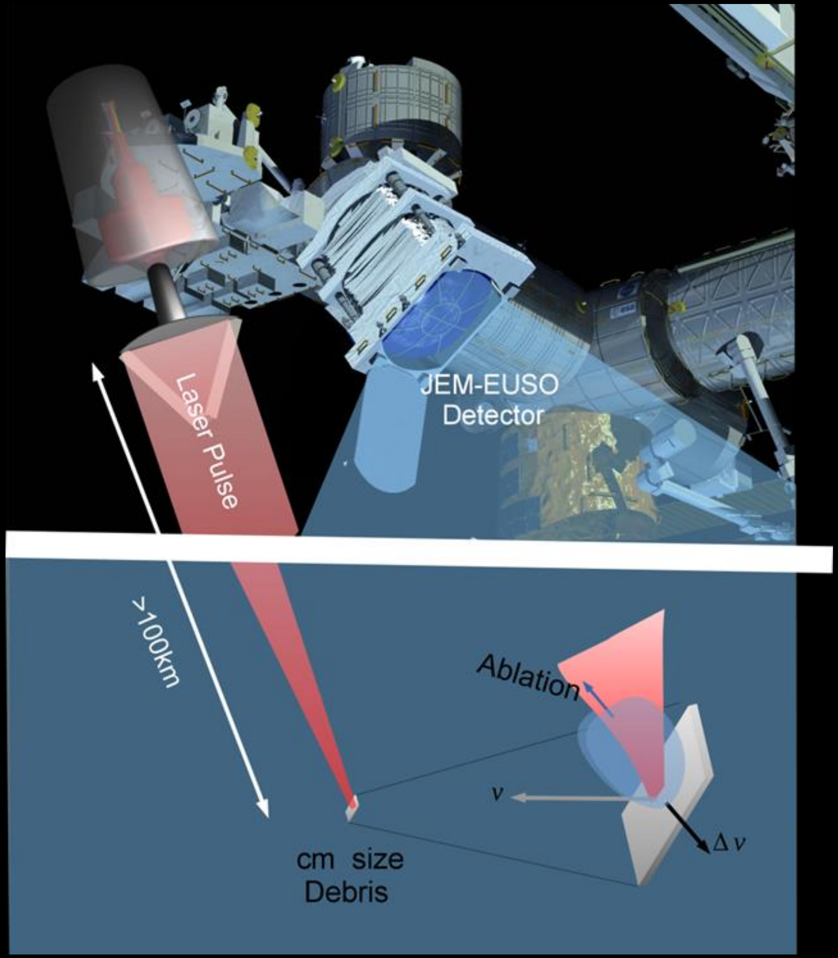
EUSO gives 60 deg FOV

- Acquisition of debris at L>100km
- Catalogue debris over orbital cycle

Provide time to point XCAN system

Burst mode of laser

Pointing along orbit?



Conclusion

Small Debris Mitigation Strategy

Small debris are difficult to be detected from the earth.

1. Their velocity and large number make them dangerous.

2. ephemerid precision (10^{-8}) is needed to evaluate collision probabity to less than 10^{8} /1.

3. This precision could be reached with stabilzed Mode-locked laser (100 fs) coupled with a streak camera in the ps regime

4. Precision also makes collision avoidance less fuel demanding.

5. Femtosecond pulses make possible:

    a. Shape measurement of debris

    b. Elemental analysis of debris for debris identification

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Space Pollution at a state of urgency

Considering the mounting activities that
Space experience, in all walks of life,
it is paramount that a serious effort be made
to develop strategies, policies, technologies to
to keep our Space Clean.

SPACE DEBRIS

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Debris Strategy : Minimize false alarms

Large dispersion in orbital position induces a large number of “false alarms”

CNES, the French Space Agency, dealt with more than 1 million collision notifications in 2016 to protect 16 satellites in Low Earth Orbit.

Because of the lack of precision 100000 notifications/1 for a serious one (10^{-4}).
Improving ephemerid accuracy to 1m would eliminate to 0 the number of false alarm.

Plus smaller change in velocity vector. Saving fuel!