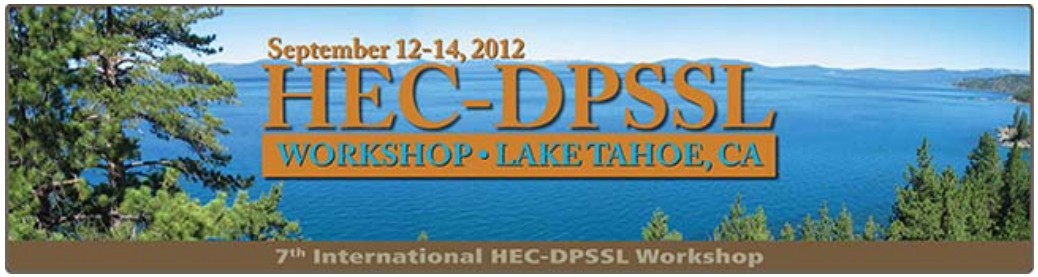
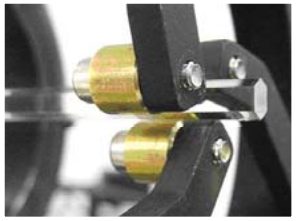


Lucia Laser chain updated status

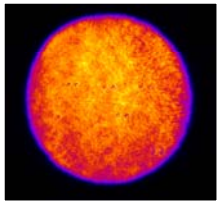
J.-C. Chanteloup, D. Albach, M. Arzakantsyan, T. Novo and B. Vincent
Laboratoire LULI, Ecole Polytechnique, Palaiseau, France

Overview

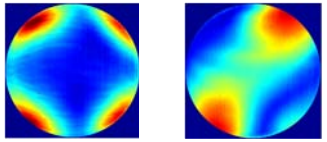
- Lucia laser chain layout



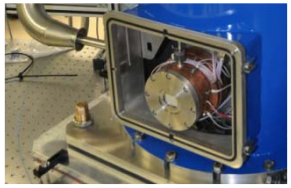
- Preamplifier stage new pump head



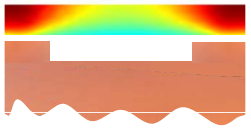
- 14 Joules extraction campaign
- Ceramics vs crystal benchmarking



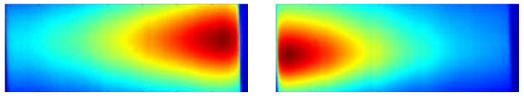
- Lucia cryogenic amplifier head



- LULI proposal for HiPER

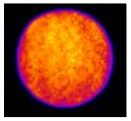
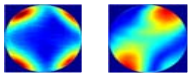
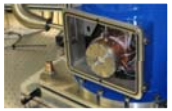
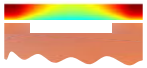
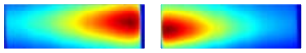


- Gradient doped activities summary

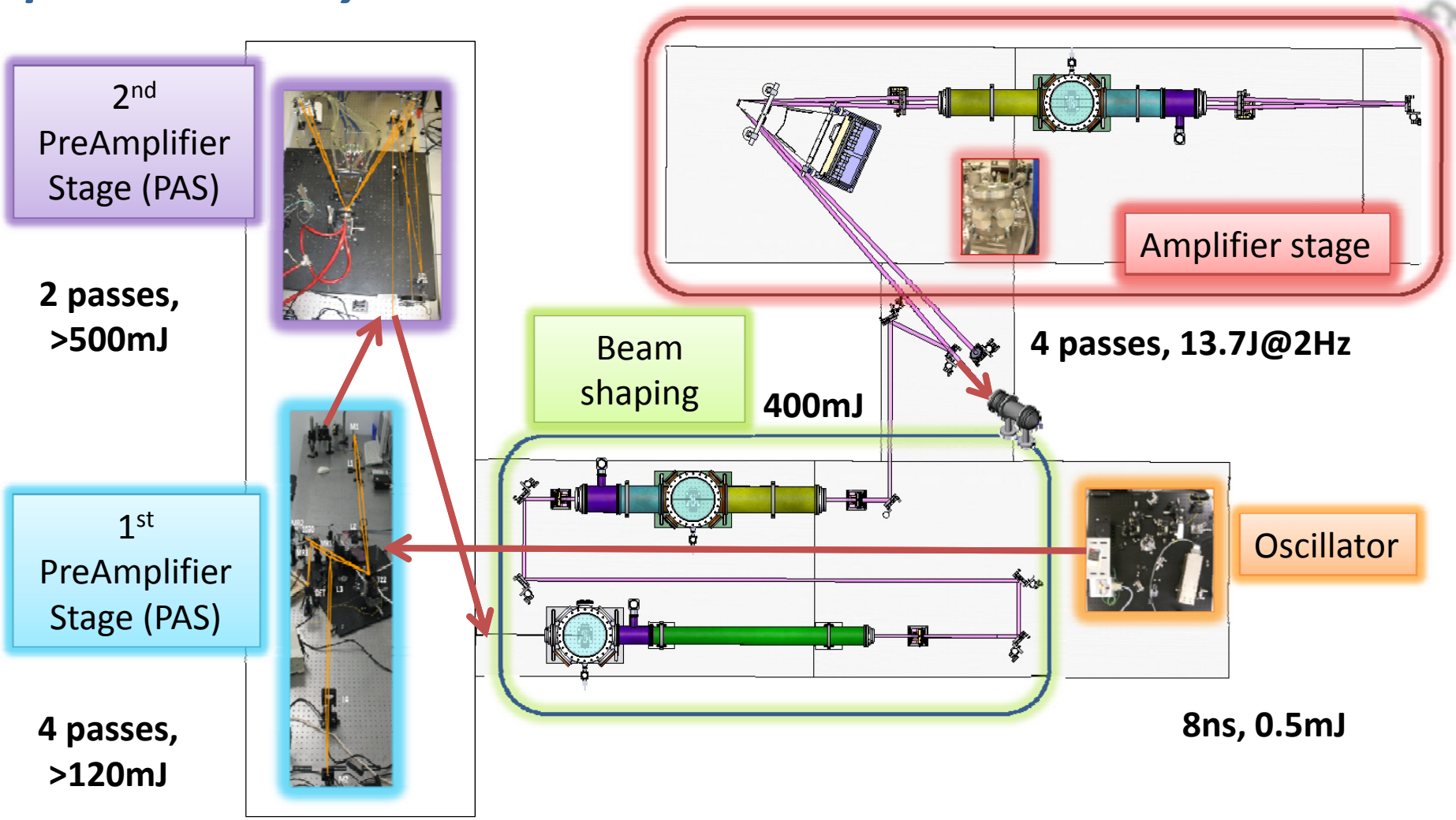


Overview

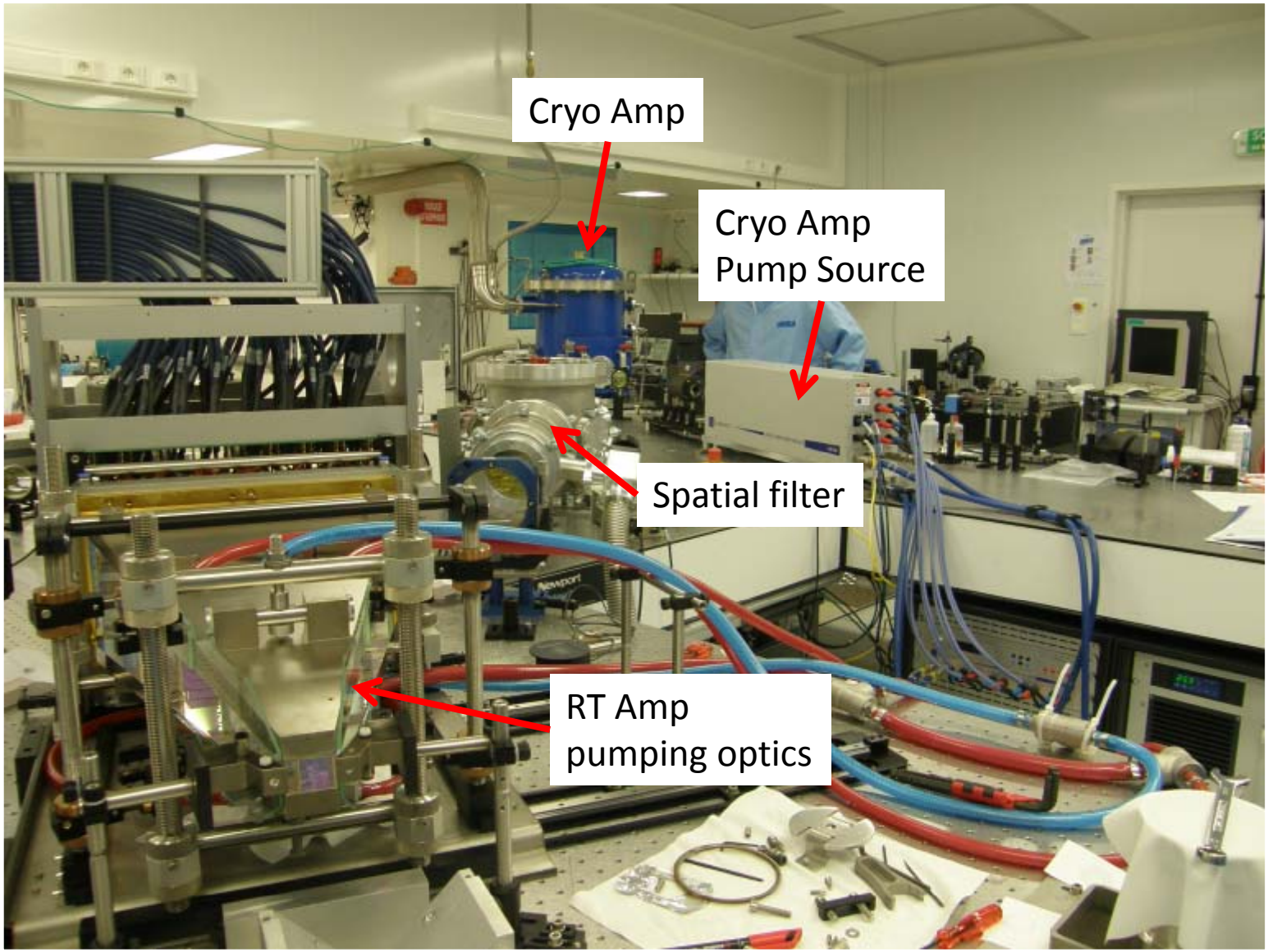
- Lucia laser chain layout
- Preamplifier stage new pump head
- 14 Joules extraction campaign
- Ceramics vs crystal benchmarking
- Lucia cryogenic amplifier head
- LULI proposal for HiPER
- Gradient doped activities summary

Diode pumped Yb:YAG Lucia laser system operational layout

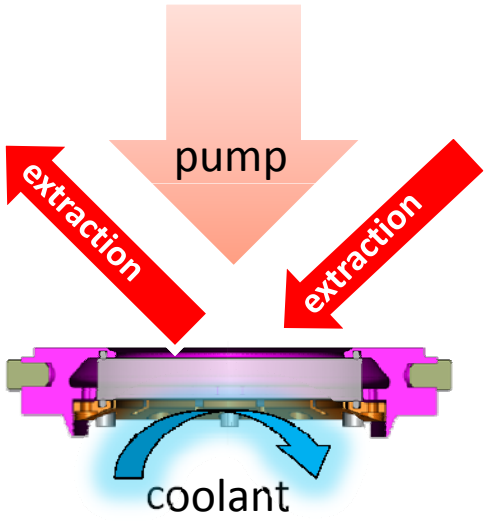


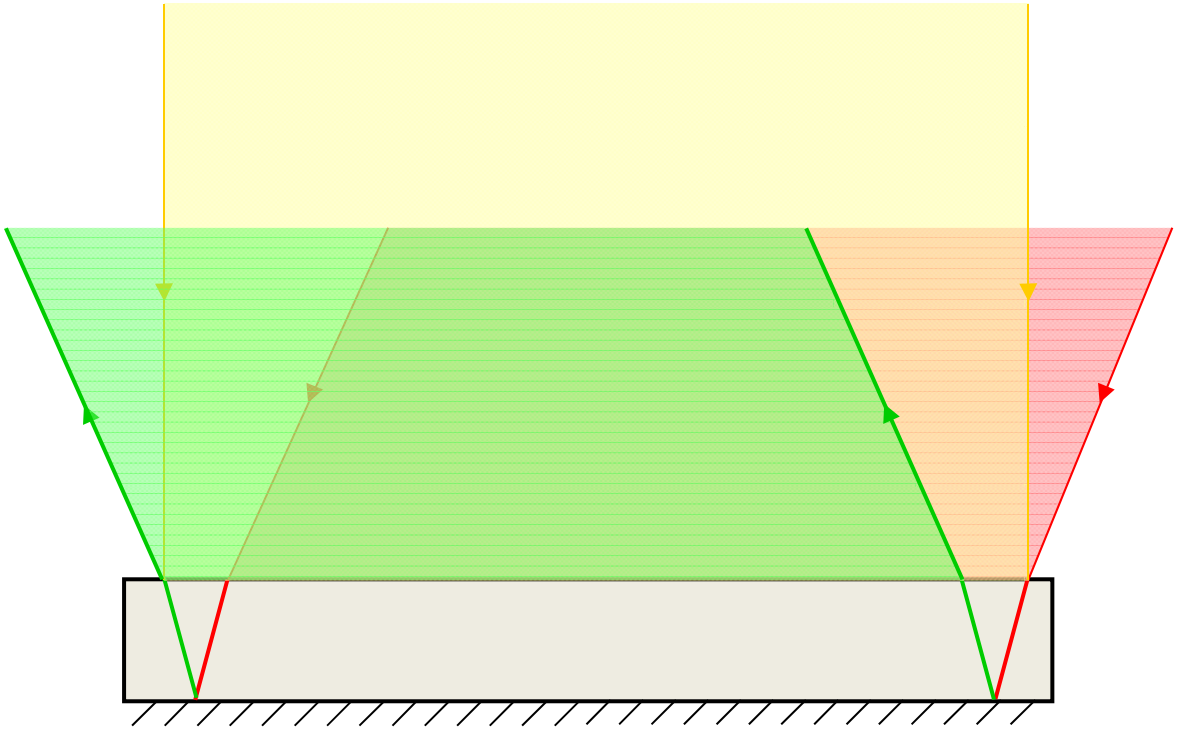
Diode pumped Yb:YAG Lucia laser system actual layout



Active mirror principle

Pump and extraction beams are reflected at the back surface of the disk





Crystal or ceramic

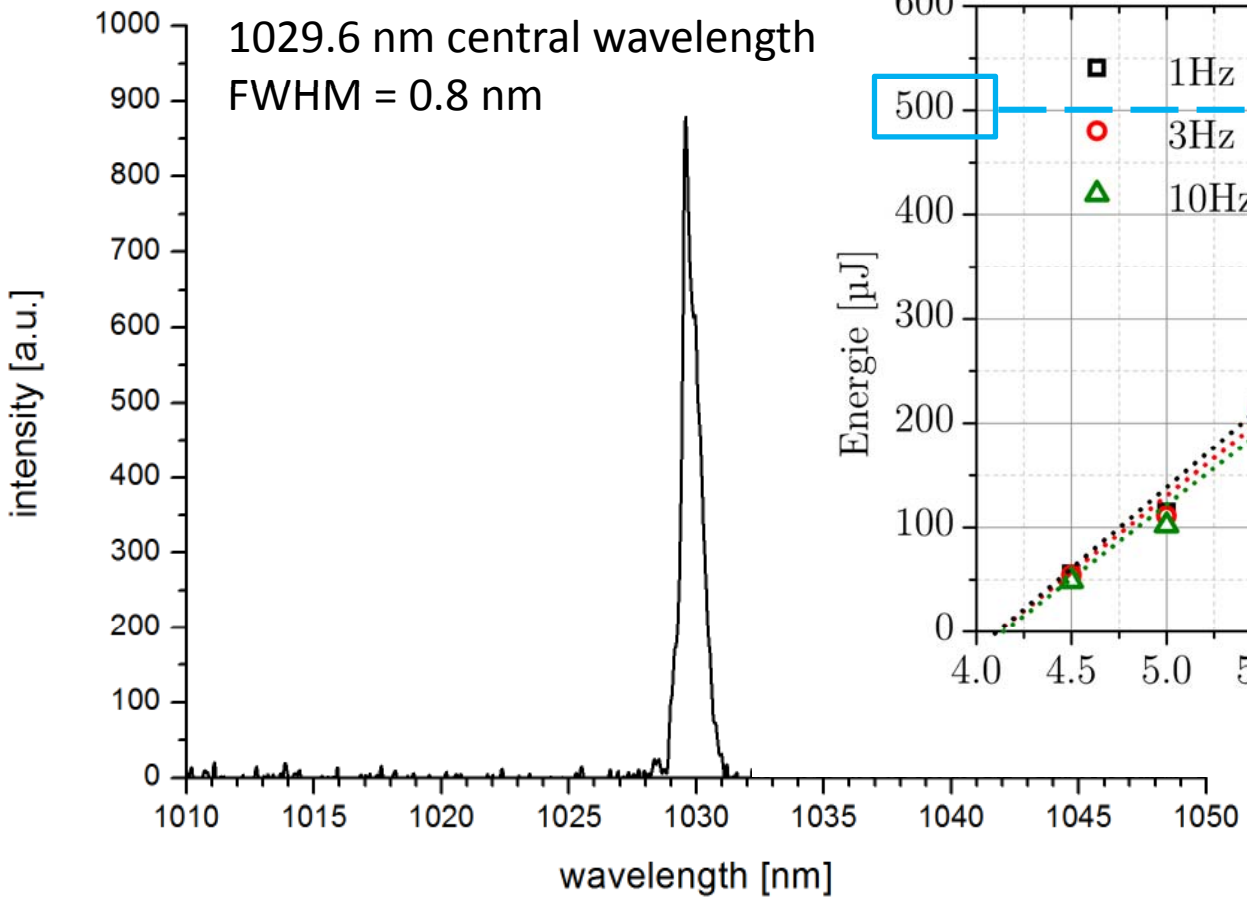
Pump beam at 941 nm

Incident beam

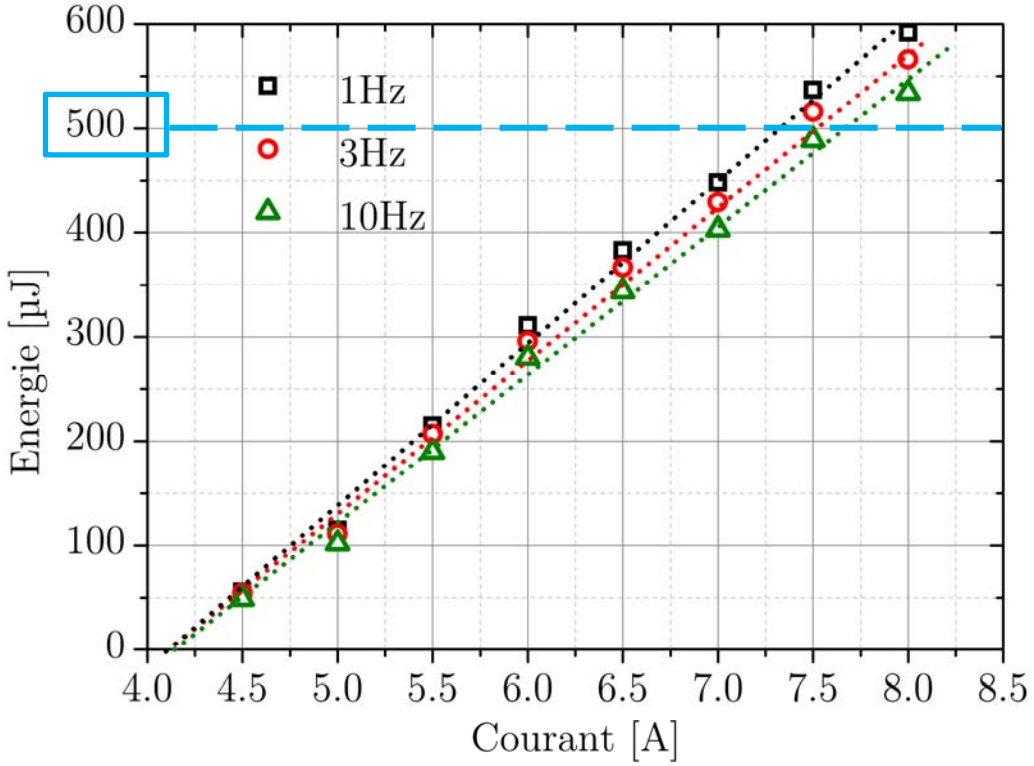
Reflected beam

at 1030 nm

Oscillator energy boosted from 300 to 500 µJ

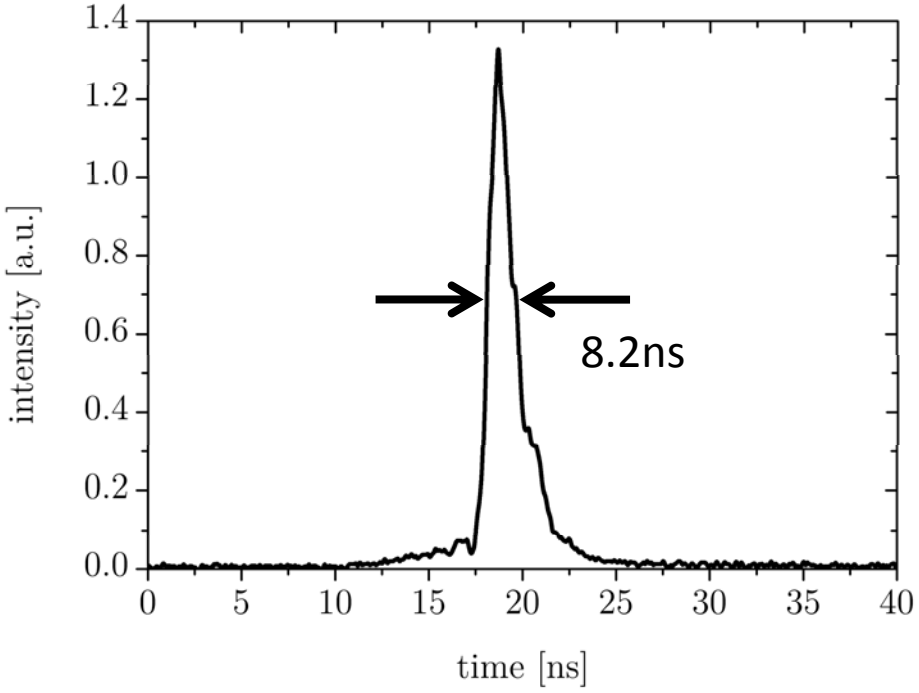


Output energy vs diode current
for 3 repetition rates.

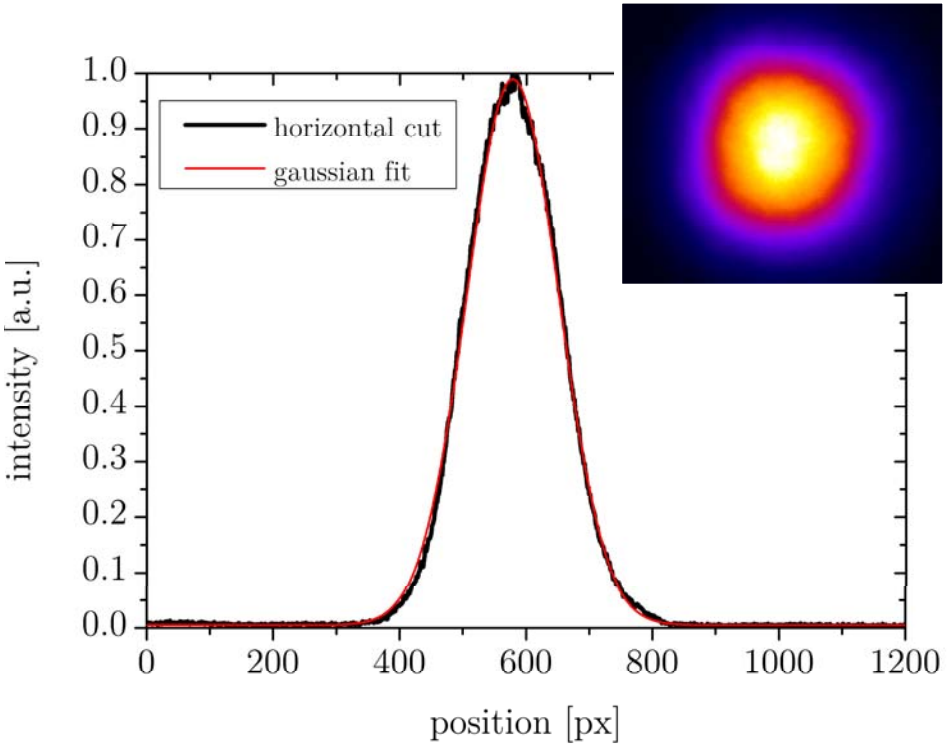


Oscillator spatial and temporal profiles

8ns / 10 Hz pulse train

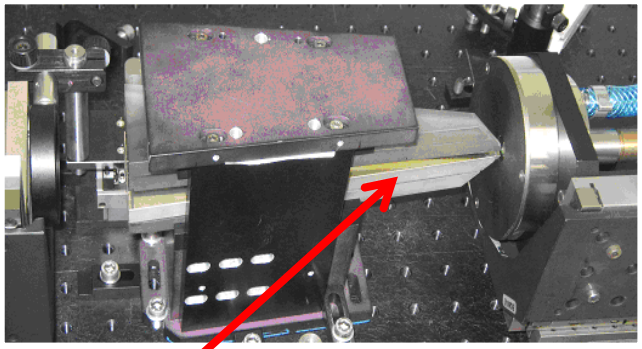


Near field profile
(8A pump intensity , 10 Hz)

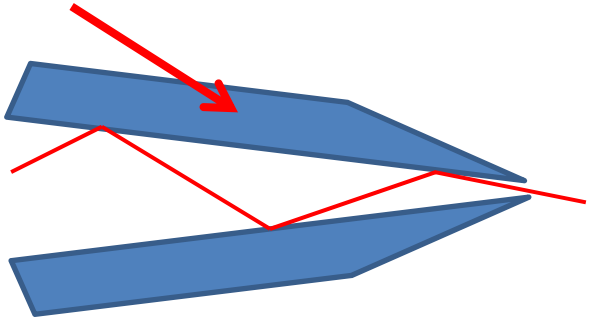


Preamplifier pumping head improved

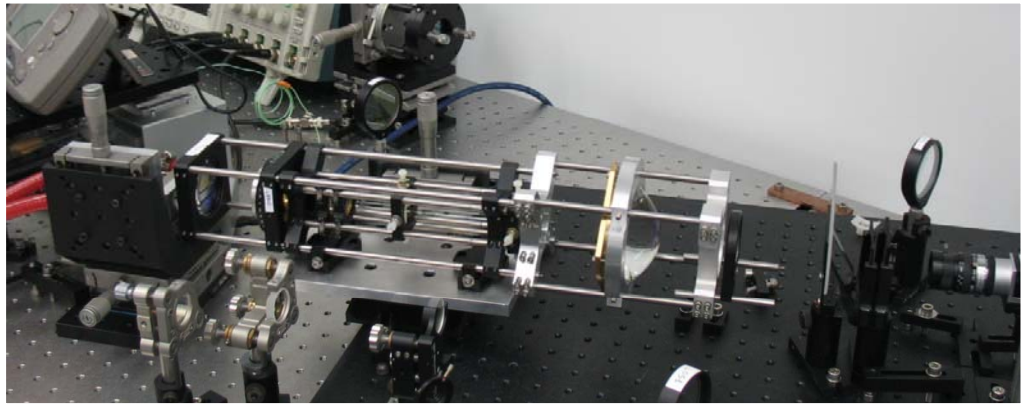
Previous pumping architecture

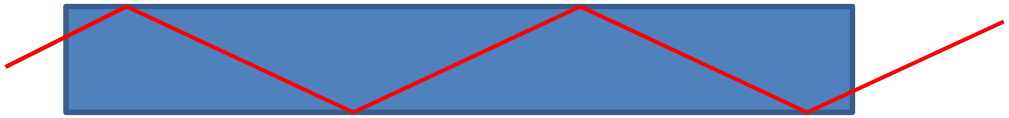


2 mirrors concentration scheme

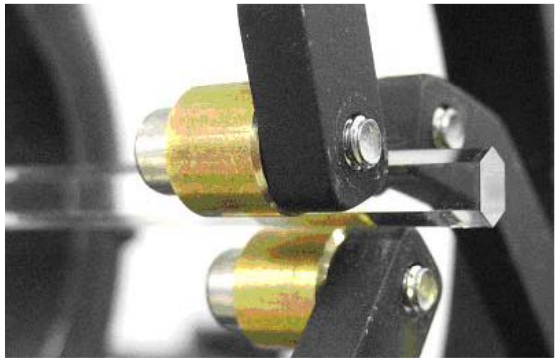


New pumping architecture



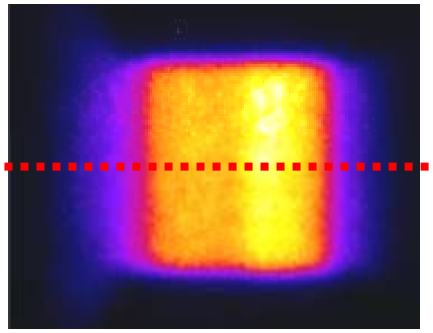


Hexagonal
bulk silica duct
(kaleidoscope)

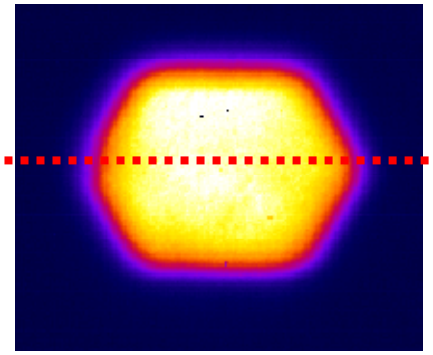


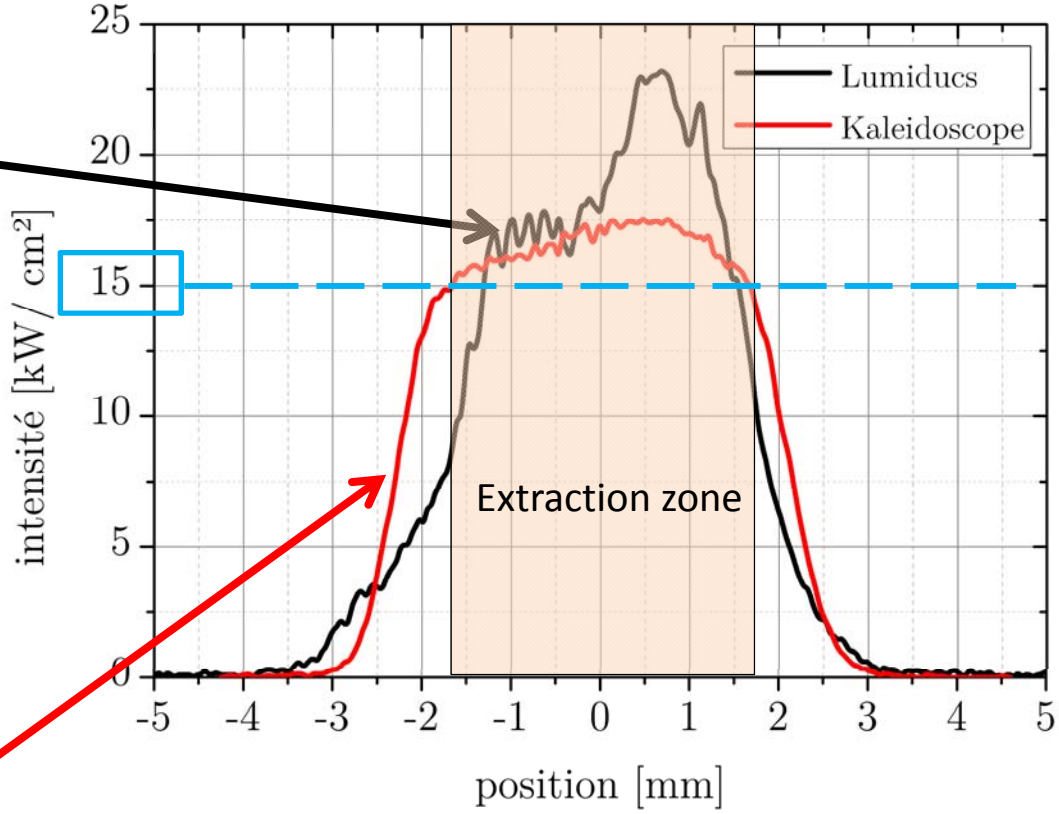
15+ kW/cm² homogeneous plateau

Old profile



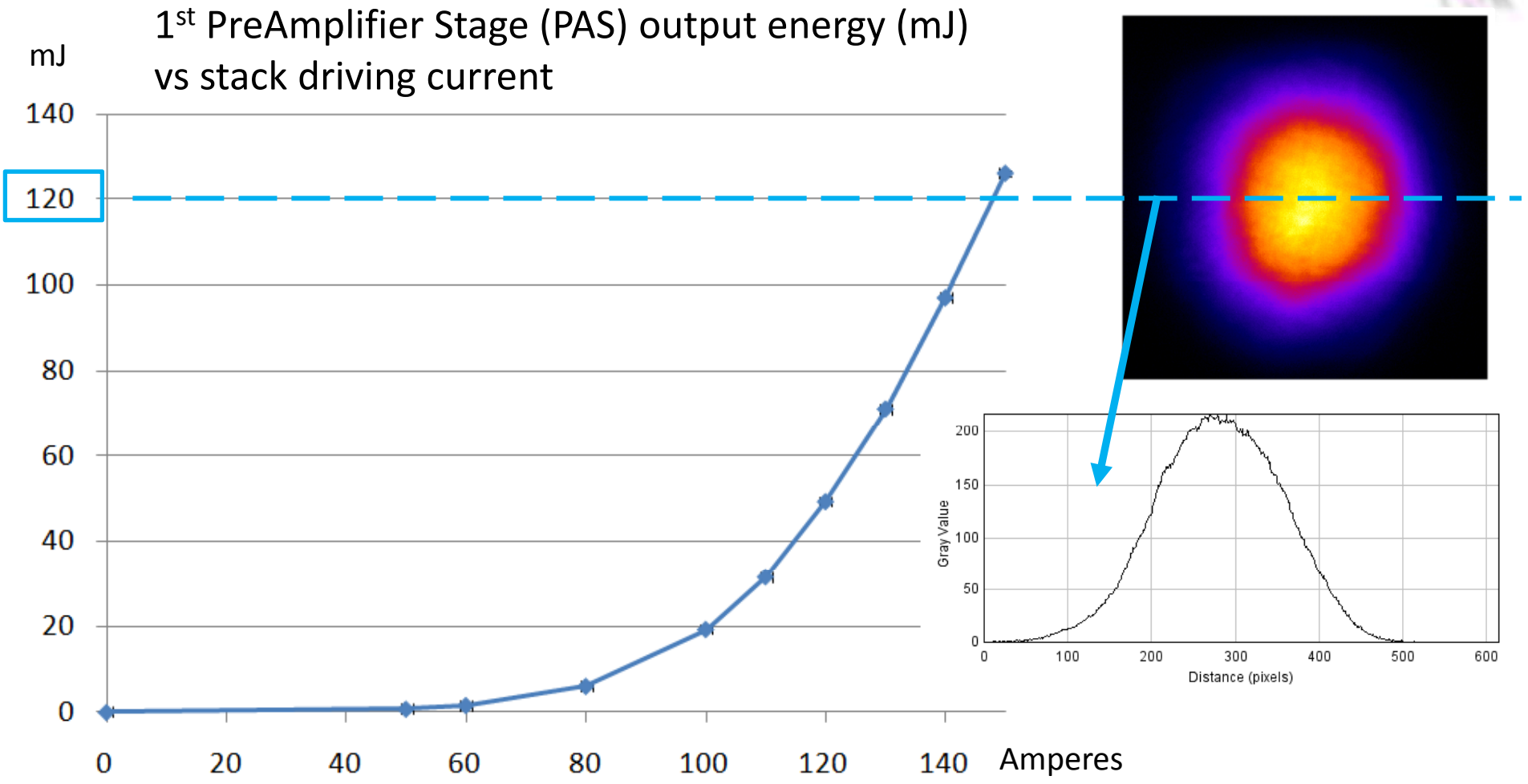
New profile



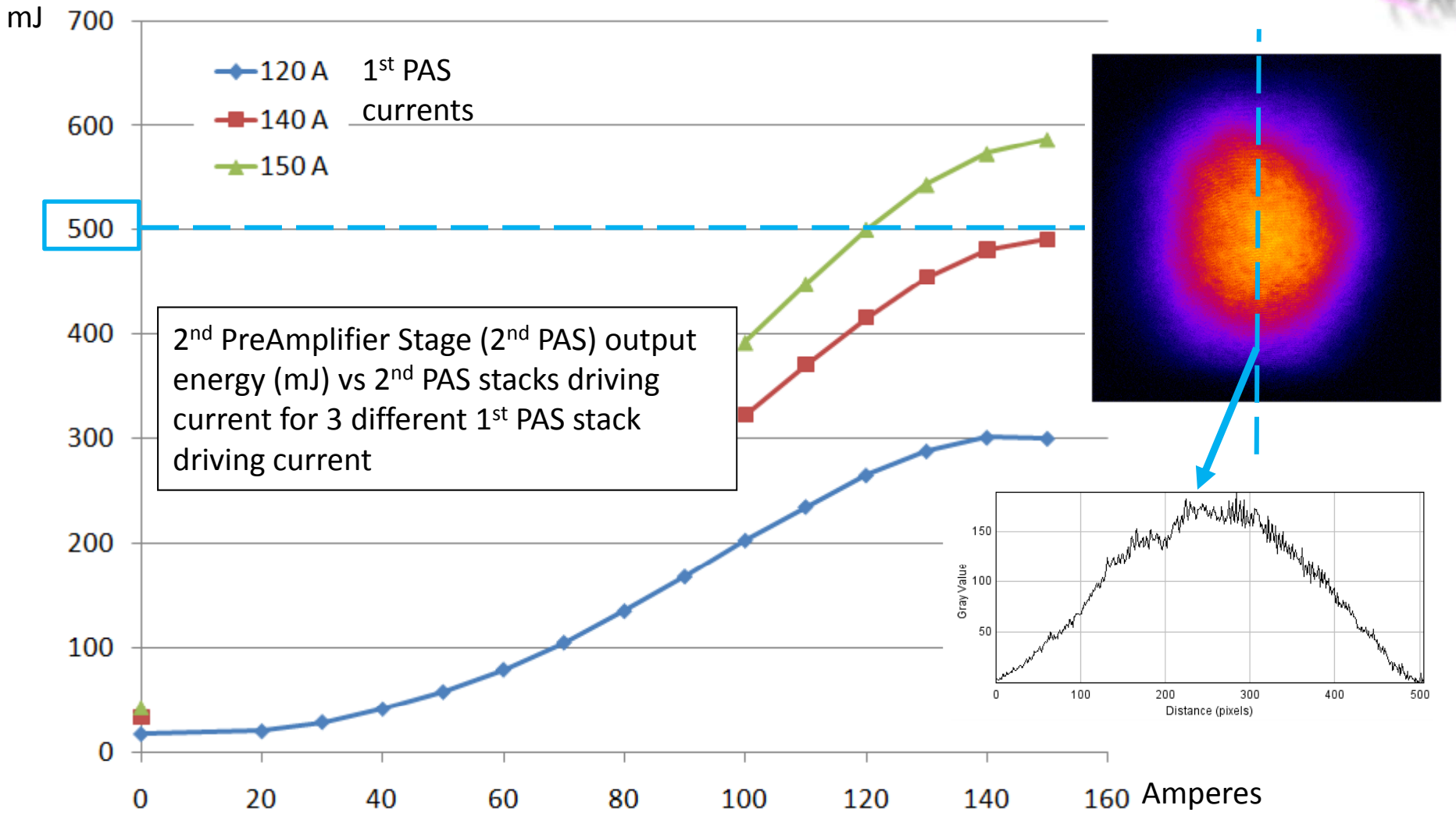


A much more homogeneous profile with a 72% transmission leading to a brightness plateau above 15 kW/cm²

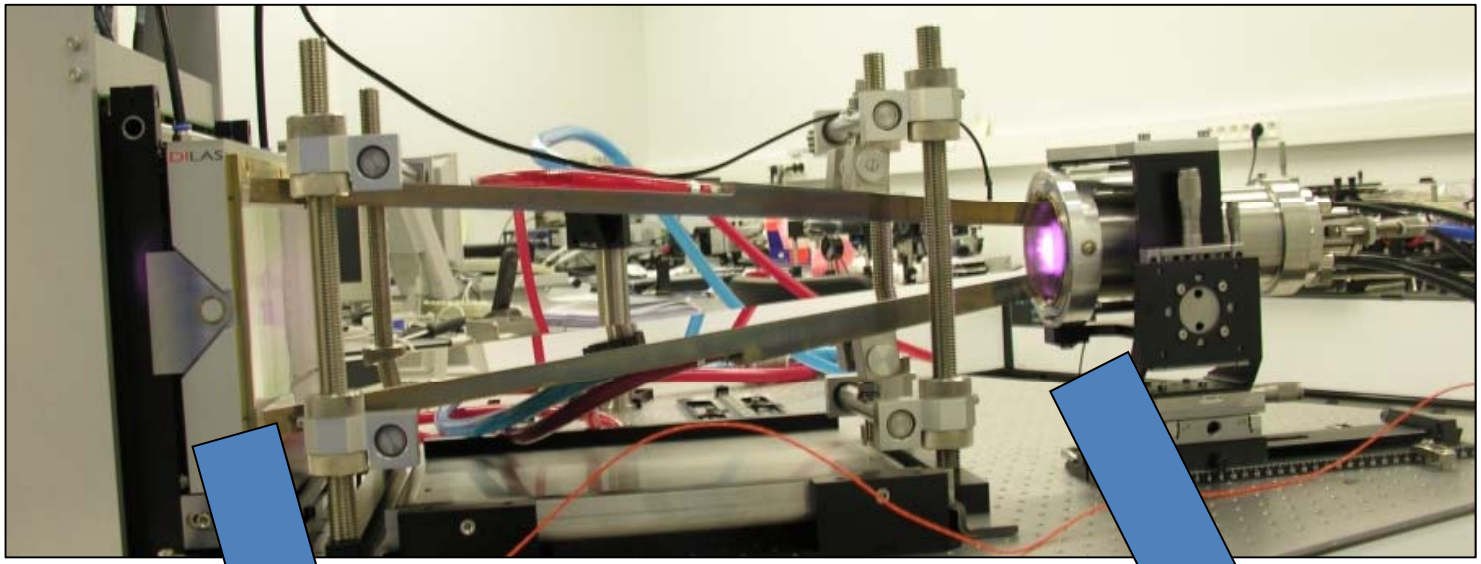
More than 120 mJ available after 1st PAS



More than 500 mJ available after 2nd PAS

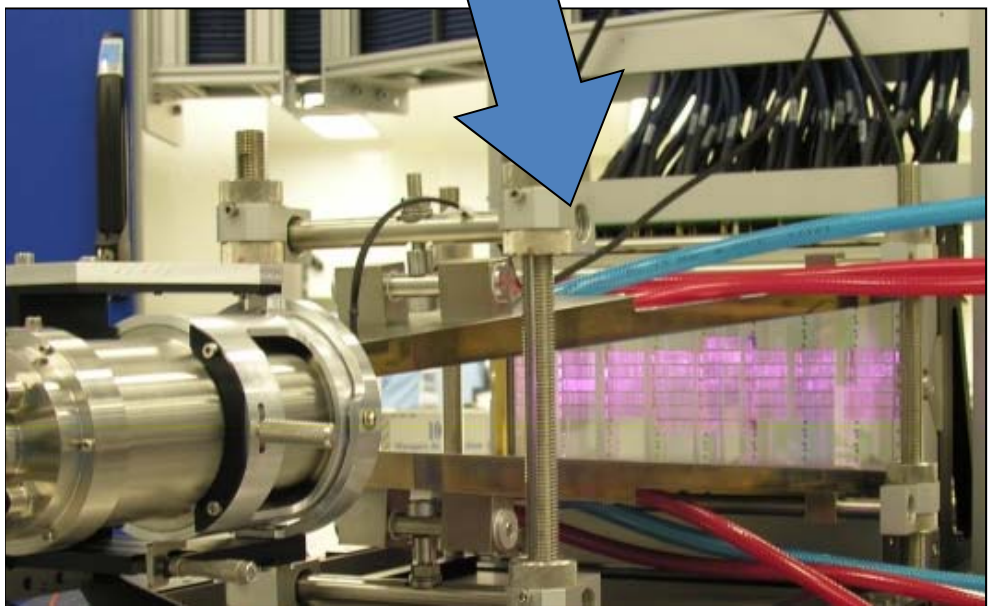


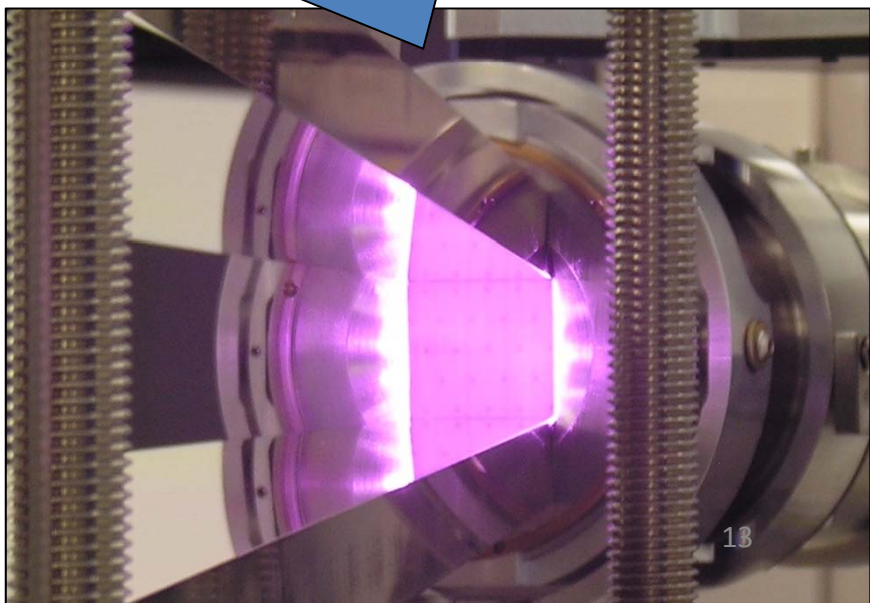
Lucia *amplifier stage*



~40 stack pumping diode array

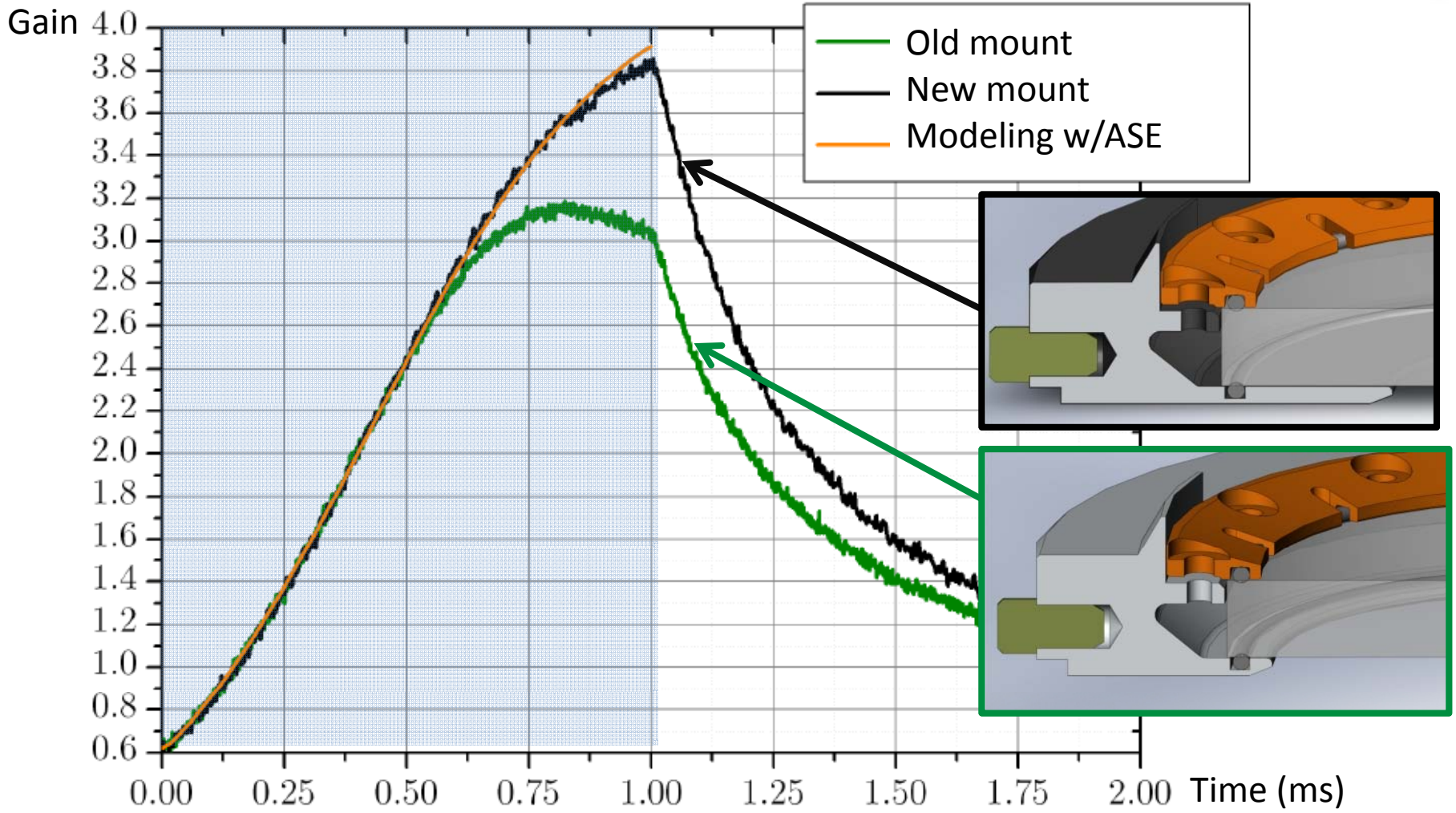
Amplifier head





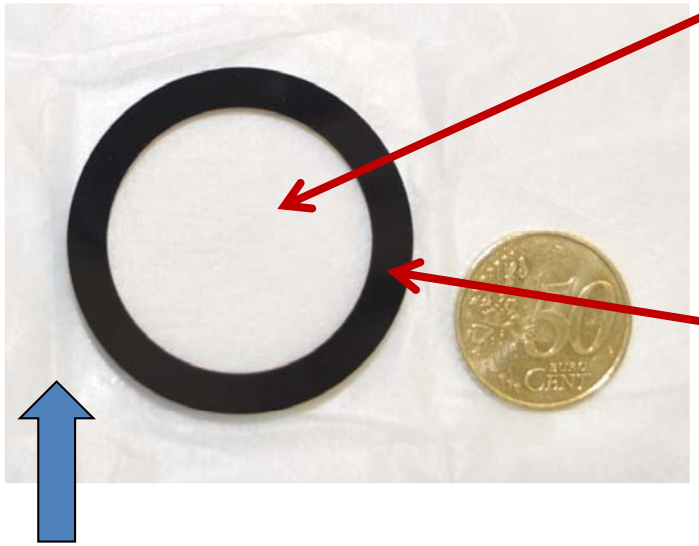
Parasitics reflections now under control

Mount periphery and mask surface reflectivities control allowed 3.8 single pass gain



Crystals & ceramics are in use on Lucia amplifier stage

60mm diameter Yb^{3+}:YAG crystal, 7mm thickness, 2at.% doped

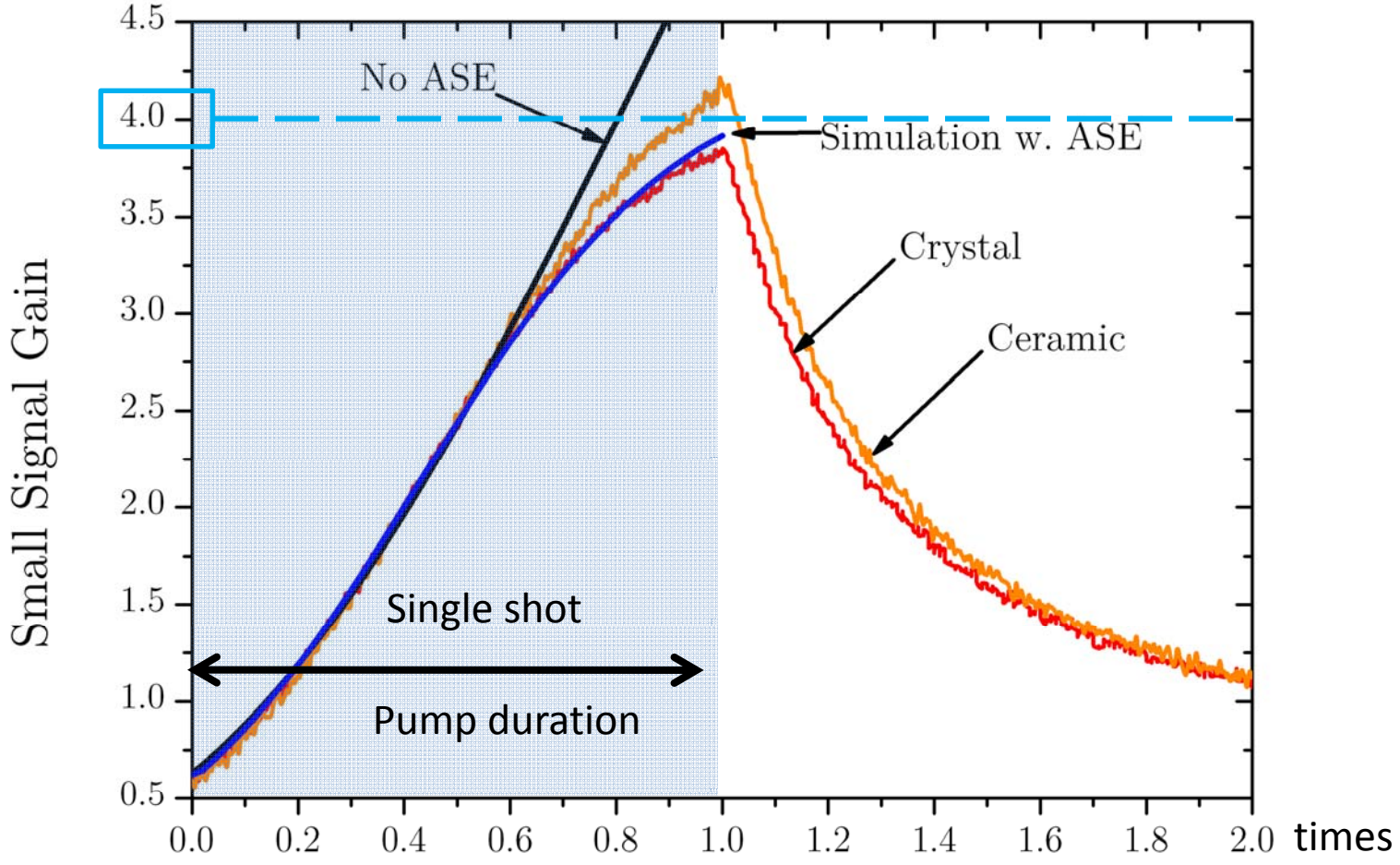


45mm diameter Yb^{3+}:YAG composite ceramics, 7mm thickness:

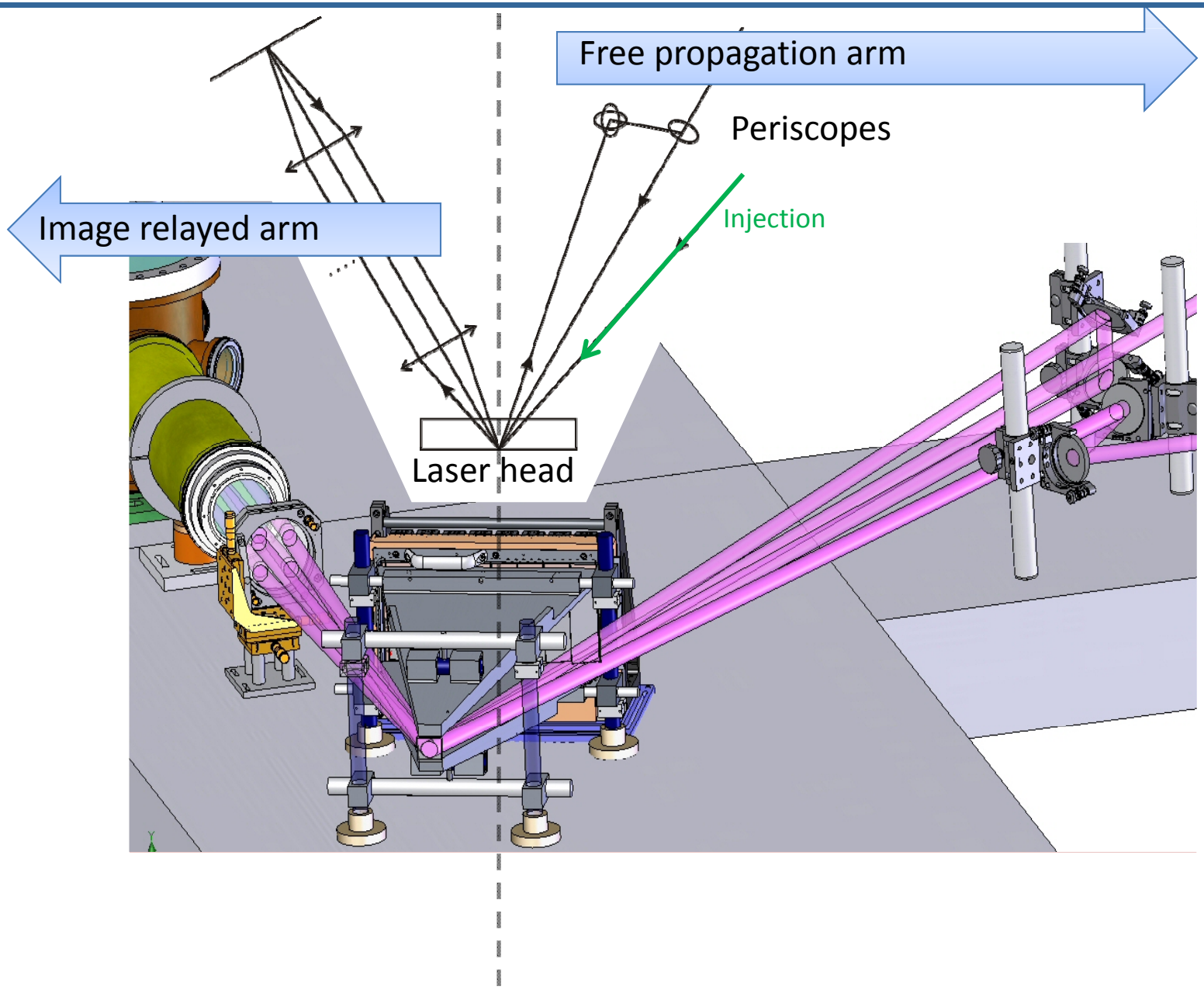
- 35mm Yb^{3+} doped center (2at.%)
- 5mm Cr^{4+} doped cladding (0.25at.%)

Crystal vs ceramic small signal gain (>4)

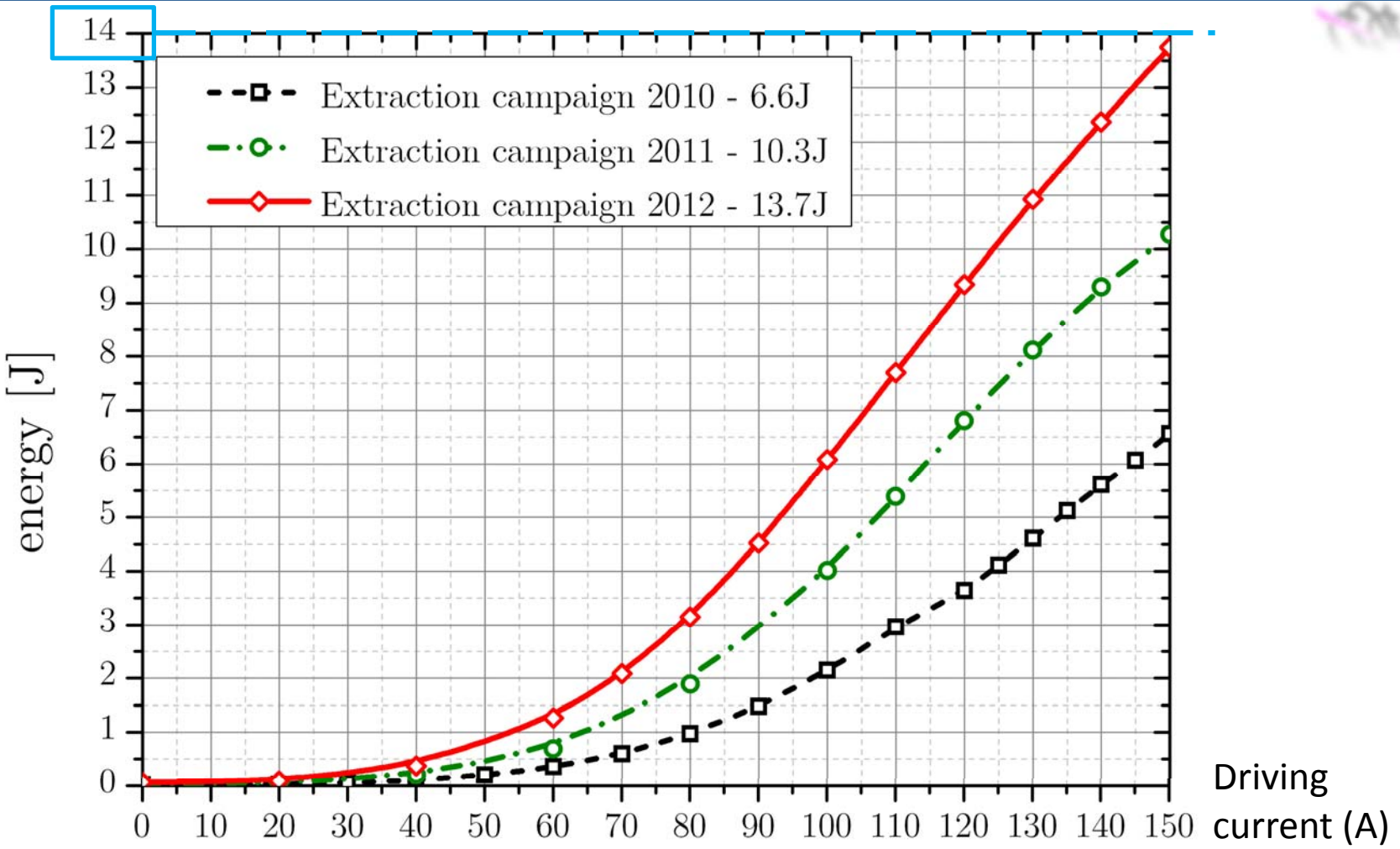
Ceramic cladding helps even more preventing parasitic lasing



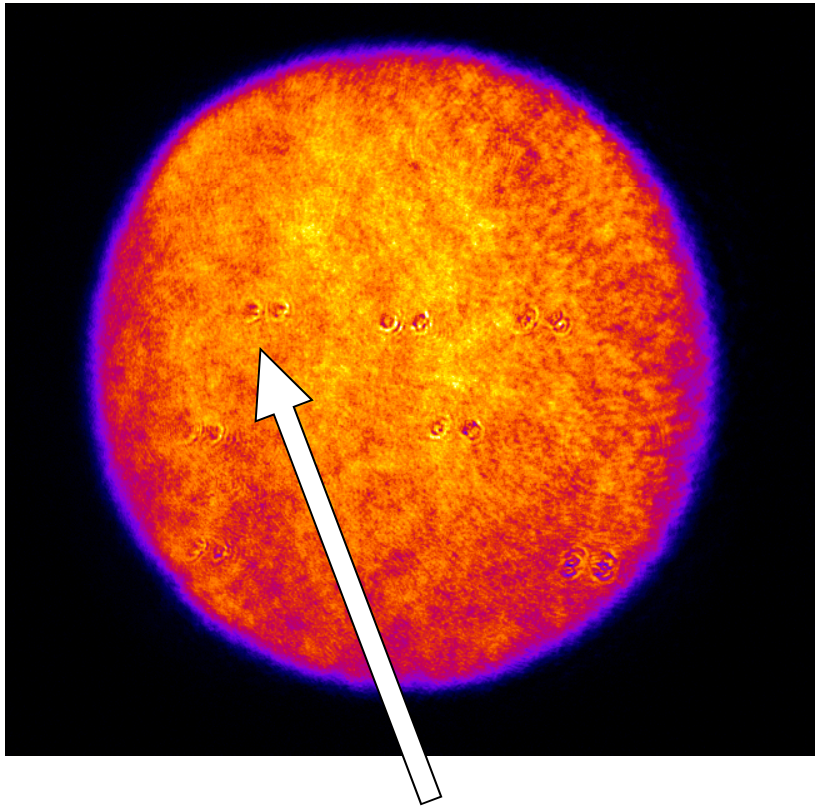
Lack of image relay was limiting extraction



~14 Joules achieved at 2 Hz

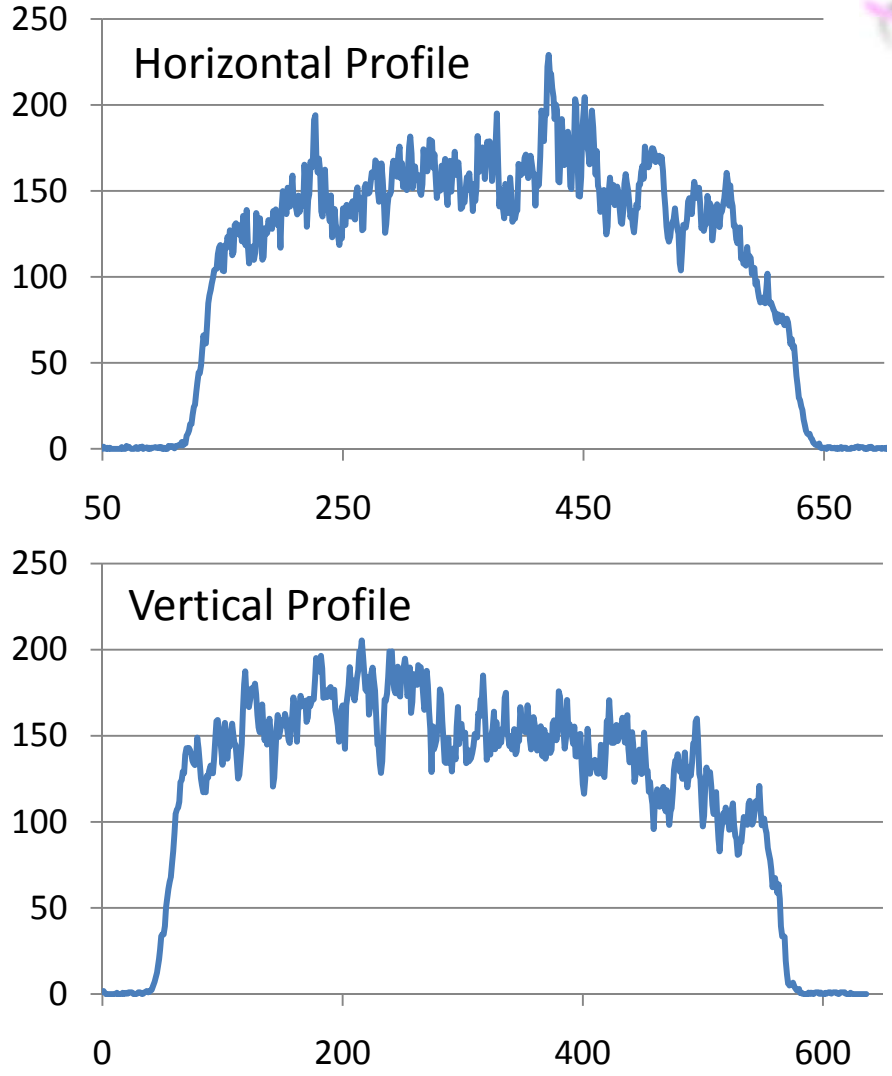


13.7 & 13.9 Joules achieved at 2 Hz with a 20 mm limited ∅



Optical damage on 0° mirror relayed onto gain medium

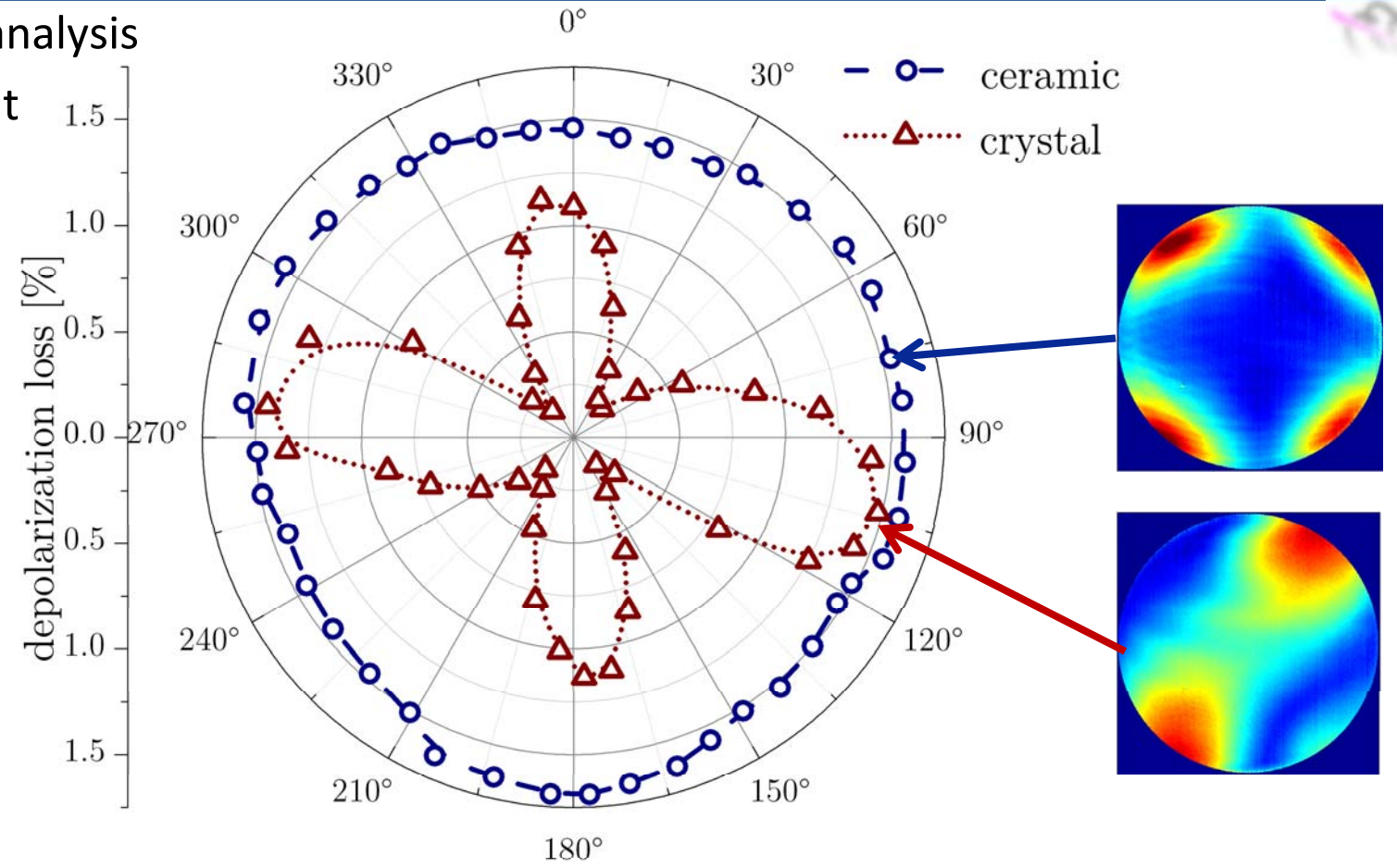
10+ more Joules stored in amplifier from which 5J might be accessible

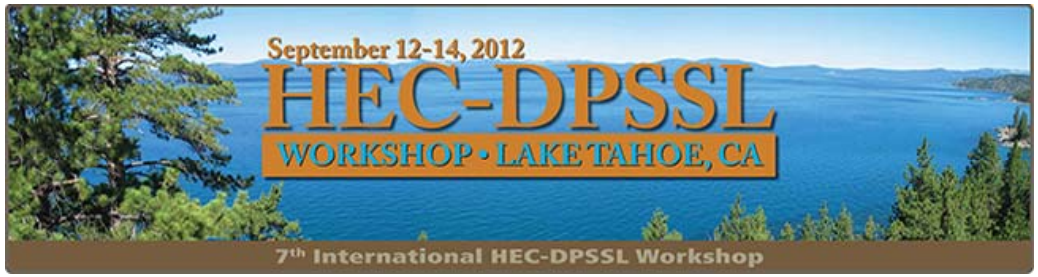


Detailed cross evaluation of crystal & ceramics performed

Depolarization analysis when pumped at 40W/cm²

A strong dependence with orientation is observed for crystal case whereas losses are constant over 360° but set at a high level





Comparison of large size Yb^{3+}:YAG ceramics and crystals

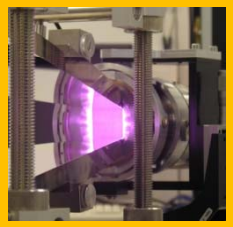
D. Albach, M. Arzakantsyan, T. Novo, B. Vincent and J.-C. Chanteloup

Laboratoire LULI, Ecole Polytechnique, Palaiseau, France

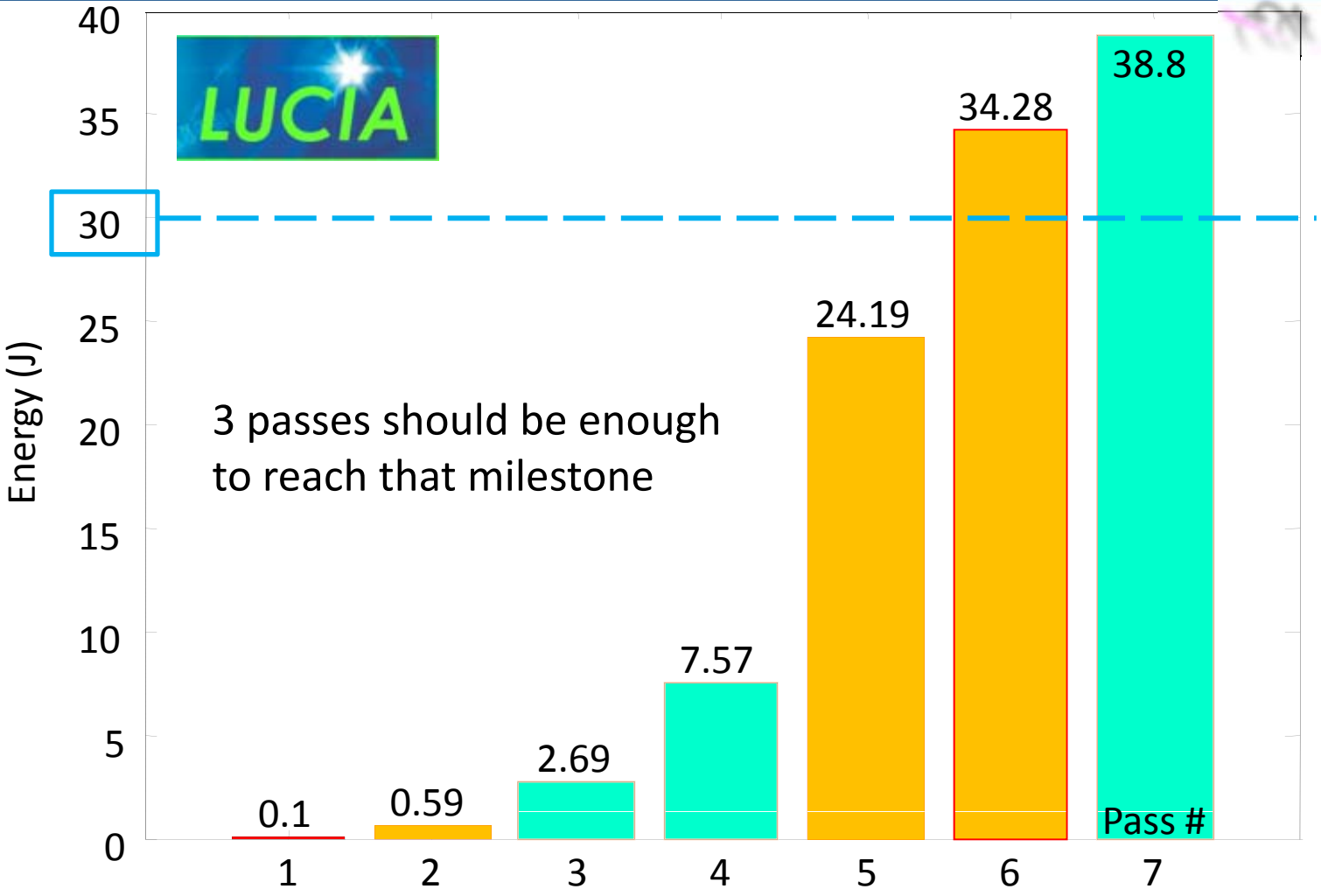
Thursday at 11:15 AM

30+ Joules should be achievable w/ 2nd cryo amplifier

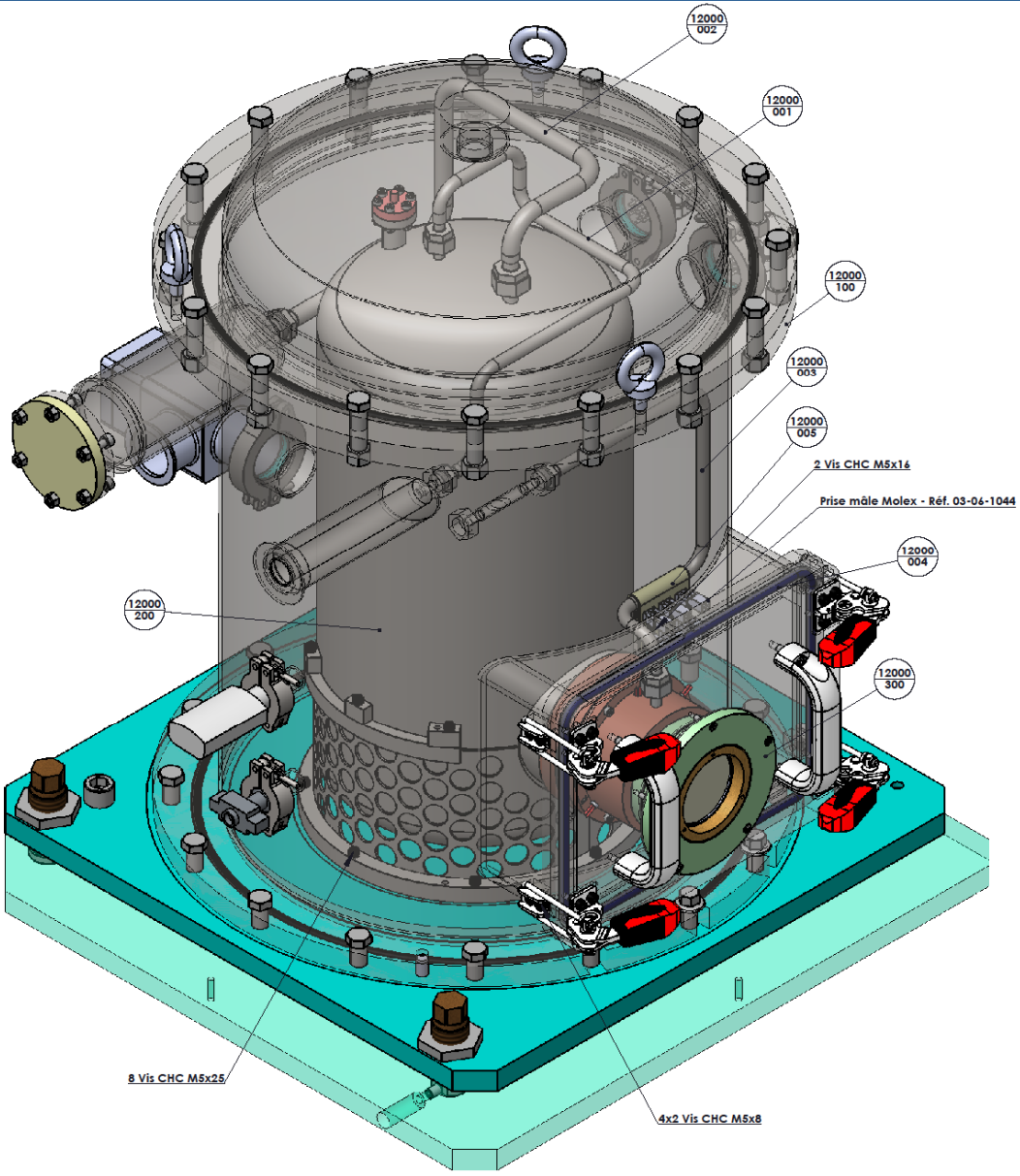
RT (300K)



Cryo (~160K)

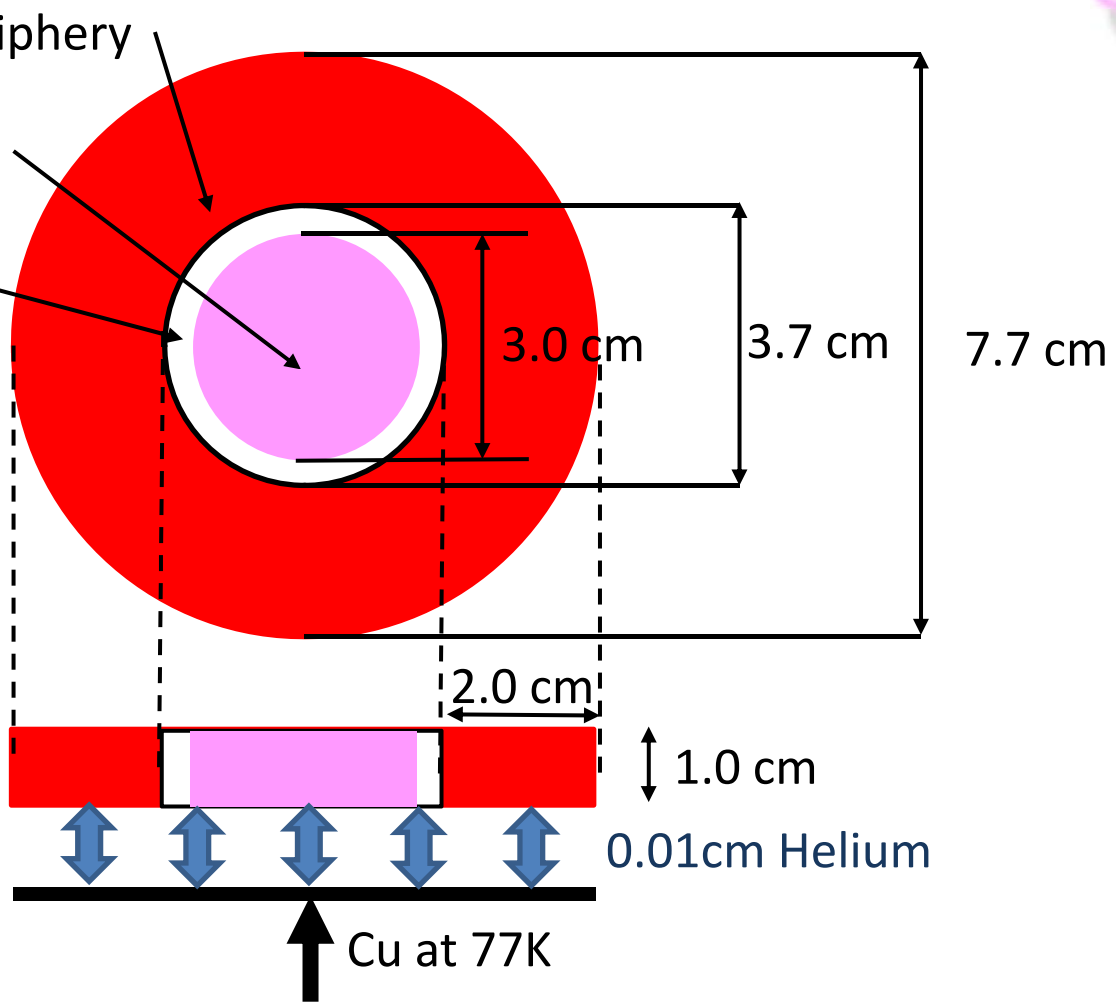


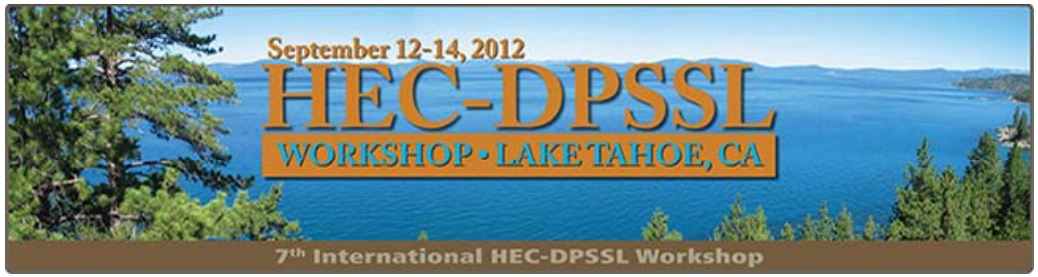
The prototype cryo head was commissioned in spring



Developed in cooperation with CEA-Grenoble / DSM / INAC/ SBT

Cr^{4+}/Yb^{3+}:YAG ceramics to be delivered end of this month





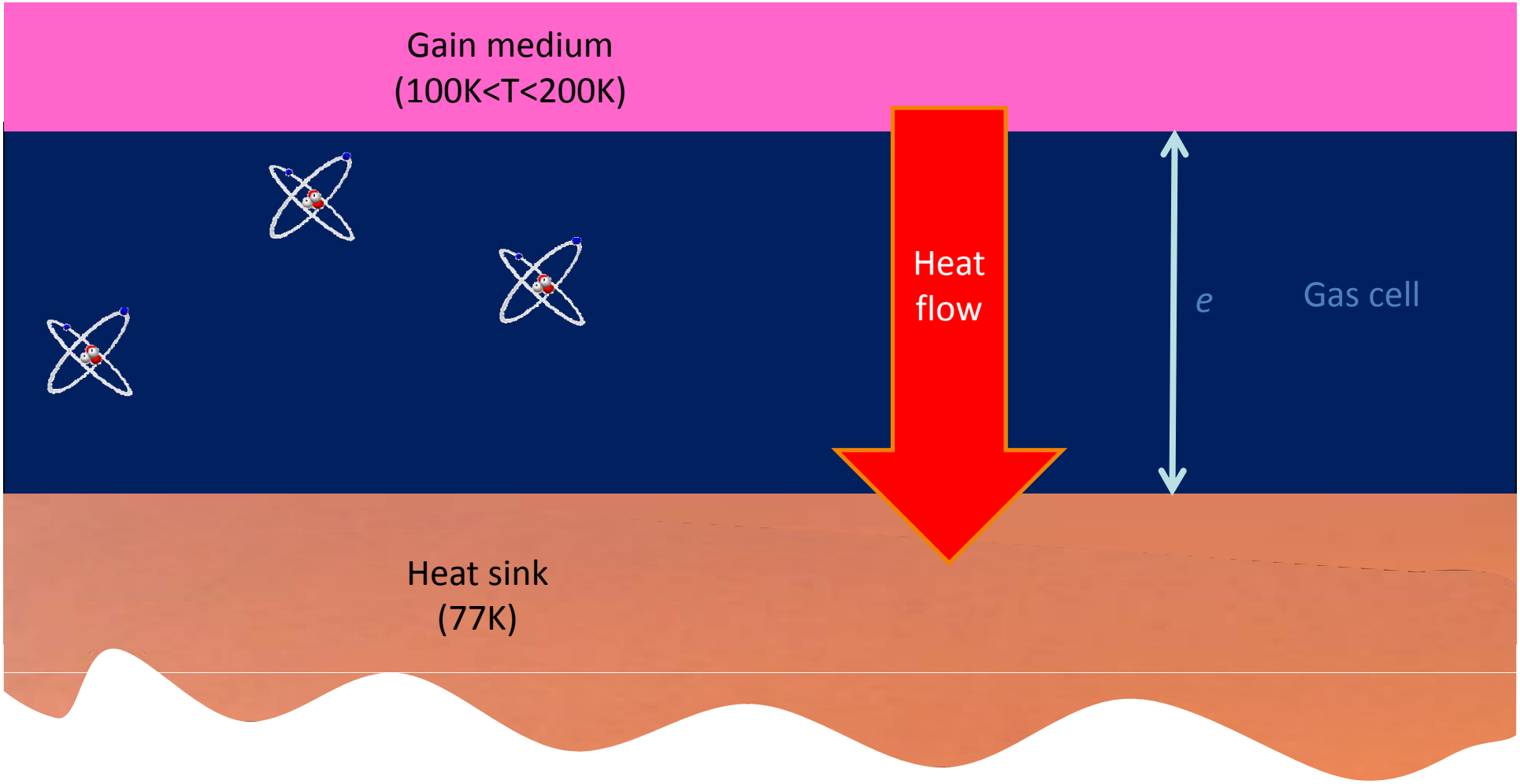
Lucia cryogenic amplifier head concept and qualification

T. Novo, D. Albach, B. Vincent and J.-C. Chanteloup
Laboratoire LULI, Ecole Polytechnique, Palaiseau, France

Friday at 09:45 AM

Gas cell thermal conductivity dependence

When the probability to hit another molecule becomes lower than hitting a wall, the thickness of the cell start impacting the thermal conductivity

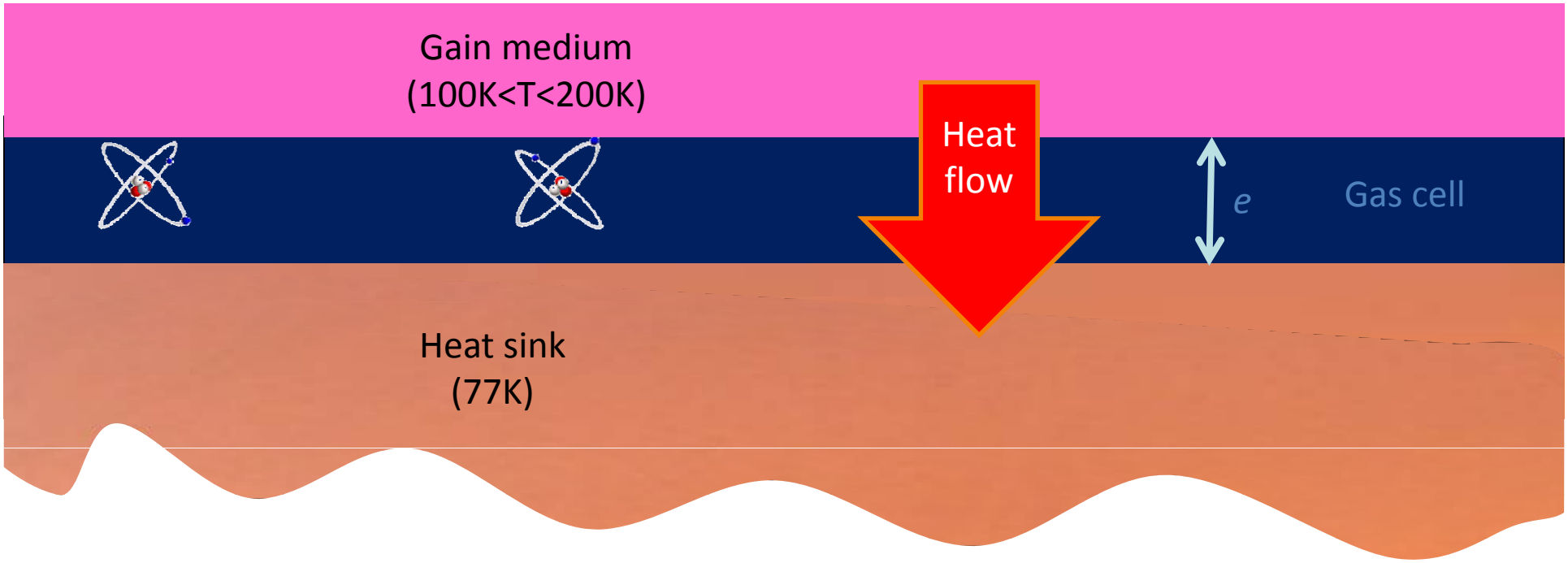


Gas cell thermal conductivity dependence

When the pressure p and/or the gap e become low enough the thermal conductivity can be described as follows :

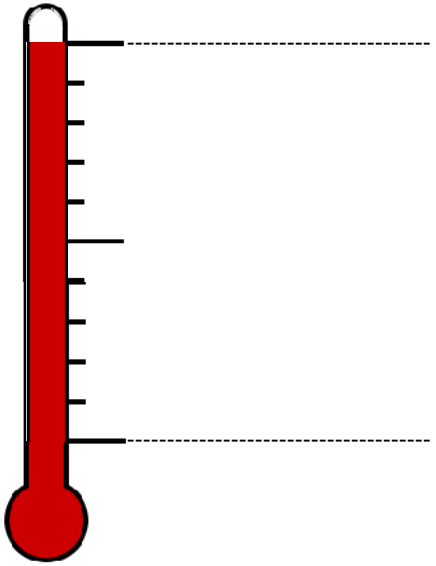
$$k(T) = k_{bulk}(T) \cdot \left(1 + \frac{8}{3} \cdot \frac{k_{bulk}(T) \cdot T}{e \cdot p \cdot \sqrt{3 \cdot R \cdot T}} \cdot \left(\frac{1}{\alpha_1} + \frac{1}{\alpha_2} - 1 \right) \right)^{-1}$$

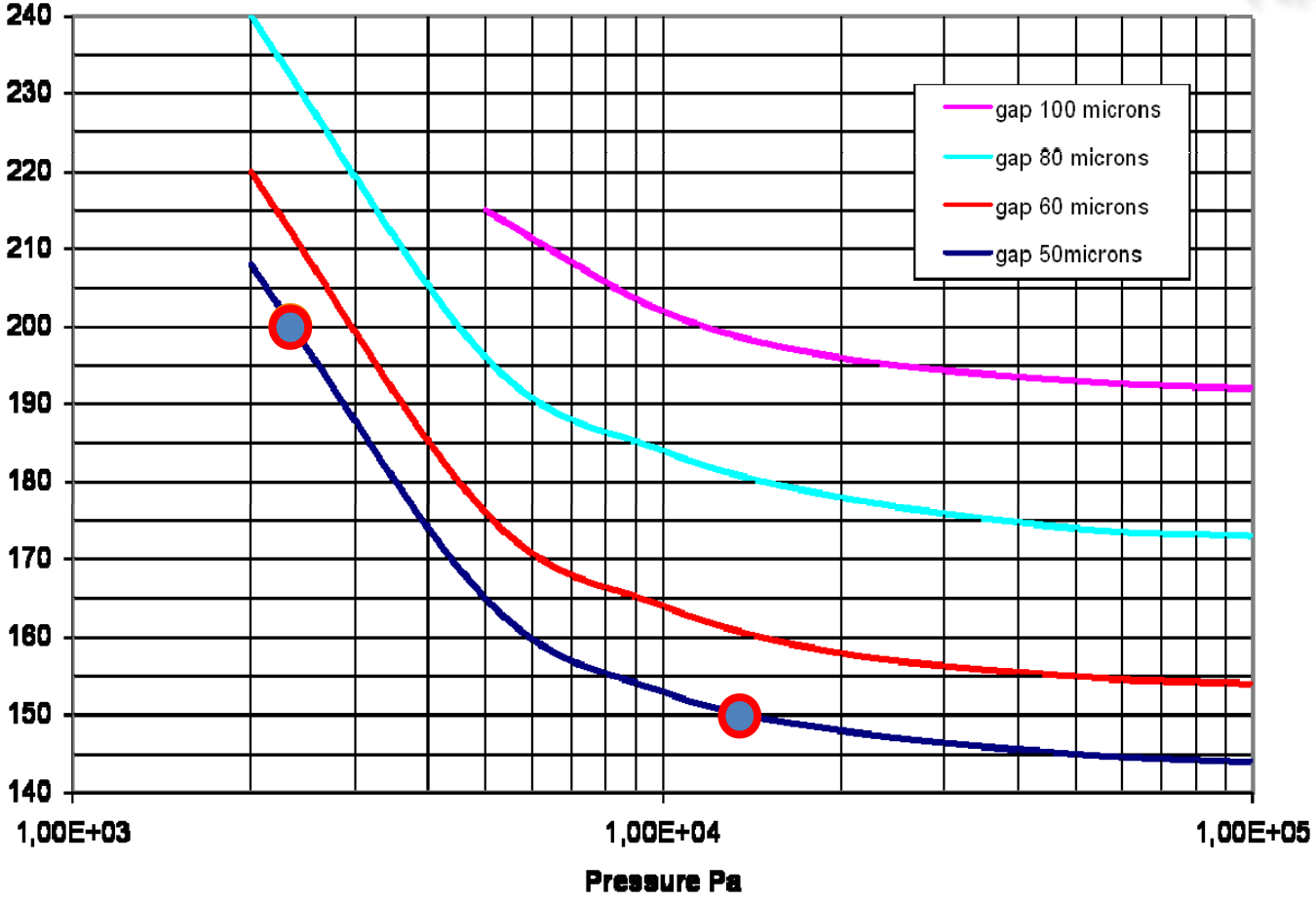
α_1 and α_2 are the thermal accommodation factors and R is the specific gas constant for Helium



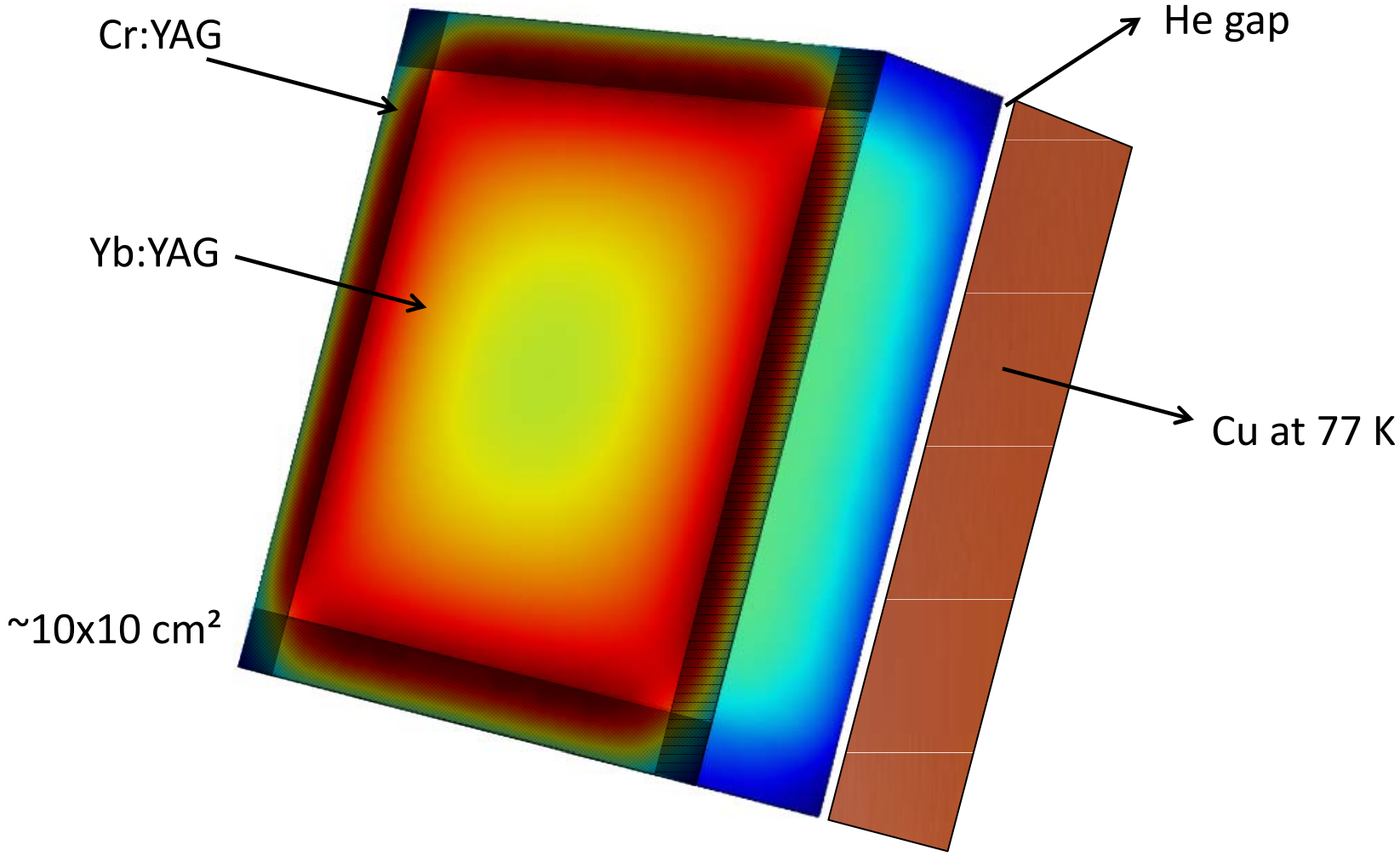
YAG fine tuning with Helium pressure

YAG temperature [K] versus pressure [Pa] for a typical HiPER heat flux to be managed : ~10 W/cm².



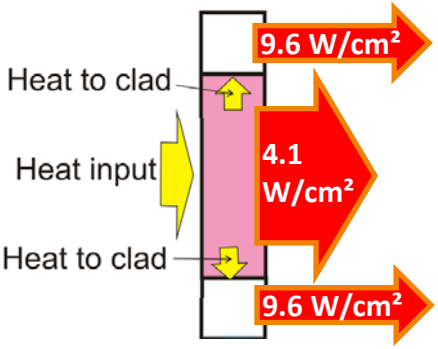


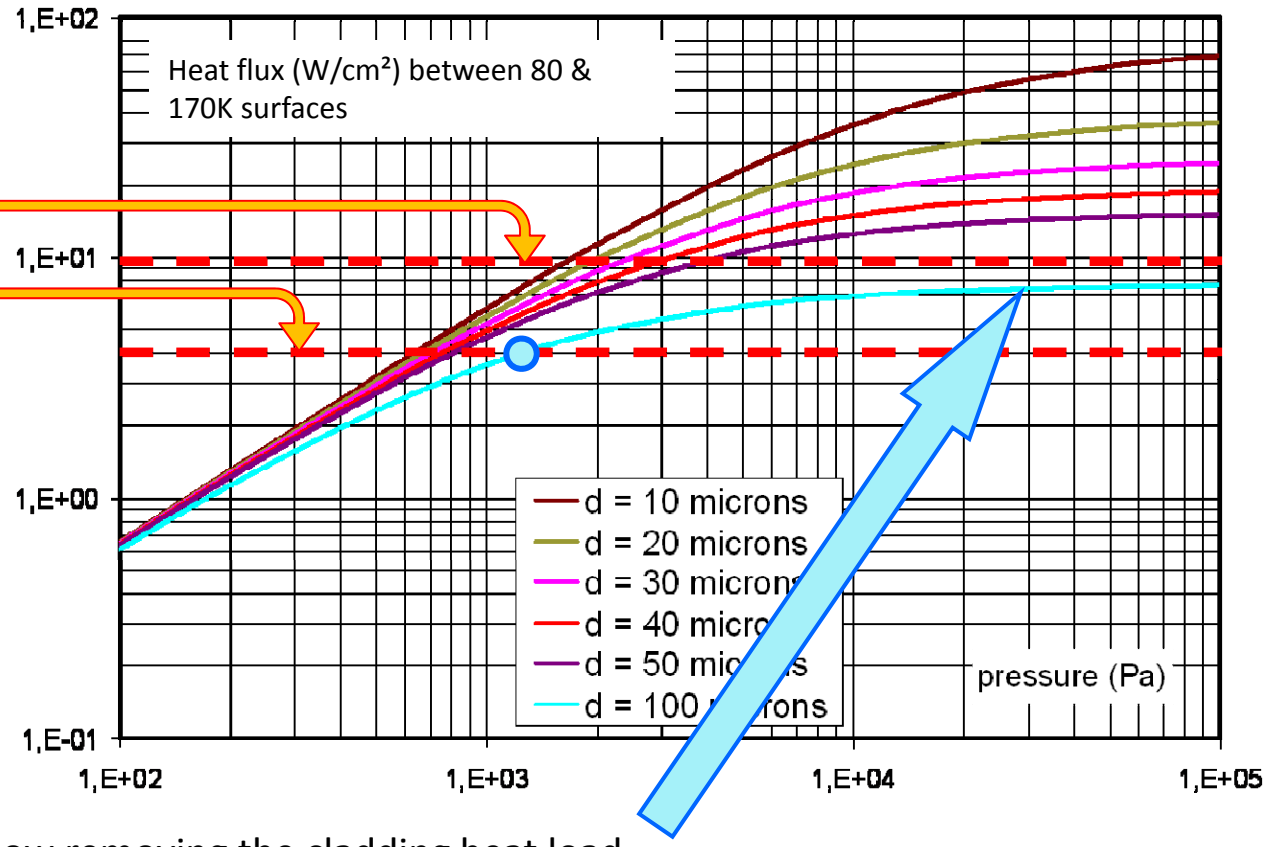
Similar approach proposed for HIPER amplifier



Need to cool both central part and cladding

Heat flux to be evacuated for HiPER amplifiers	
4 cm cladding	9.6 W/cm²
Gain medium	4.1 W/cm²



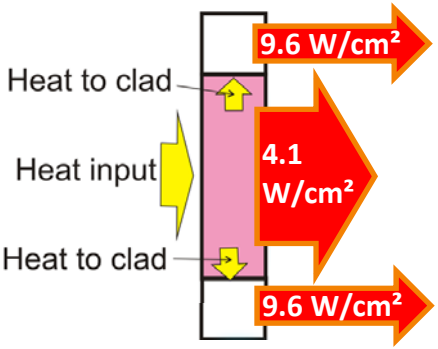


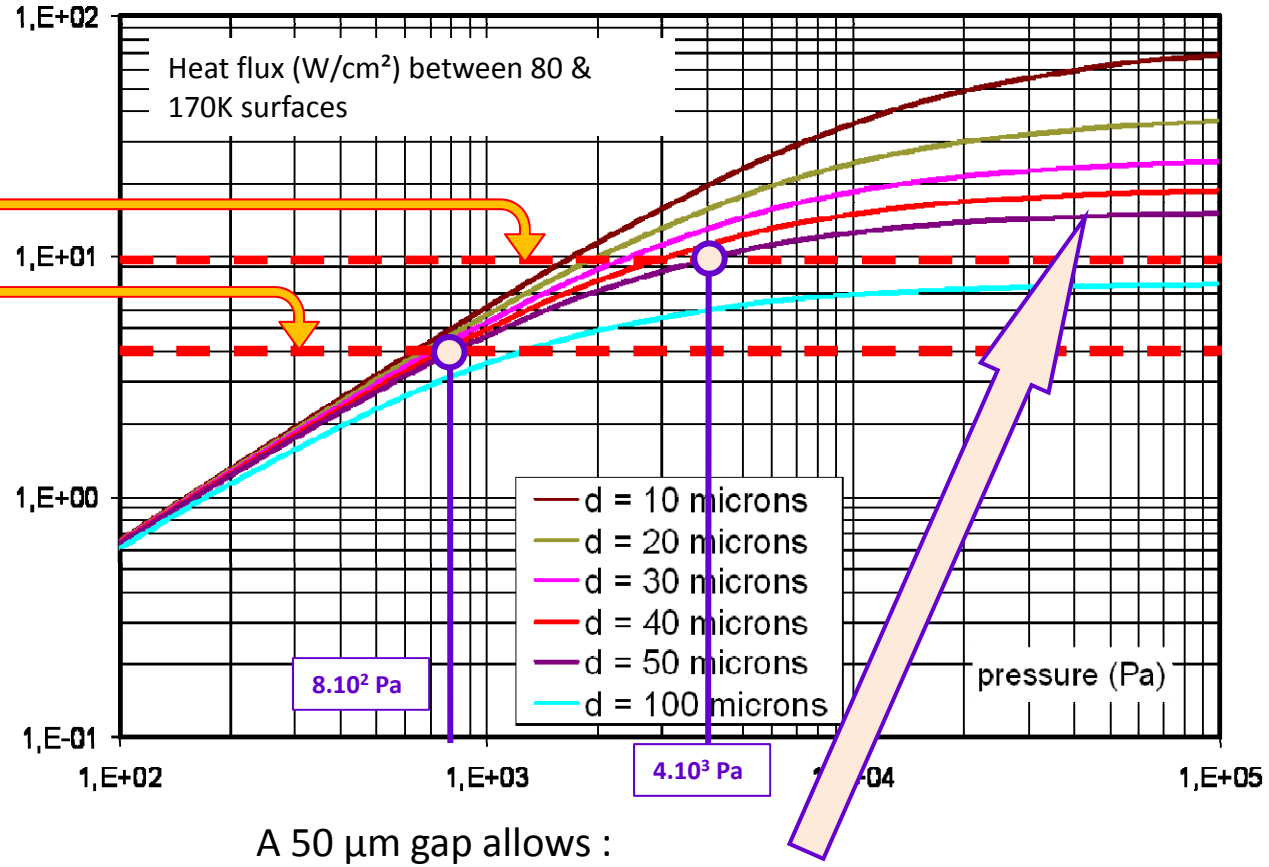
A 100 µm gap would not allow removing the cladding heat load.
The curve never reach the 9.6 W/cm² threshold even by increasing the pressure up to the 10^5 Pa.

But such gap is sufficient to remove the heat load in the gain medium,
providing a pressure around 1 millibar (10^3 Pa).

Need to cool both central part and cladding

Heat flux to be evacuated for HiPER amplifiers	
4 cm cladding	9.6 W/cm²
Gain medium	4.1 W/cm²





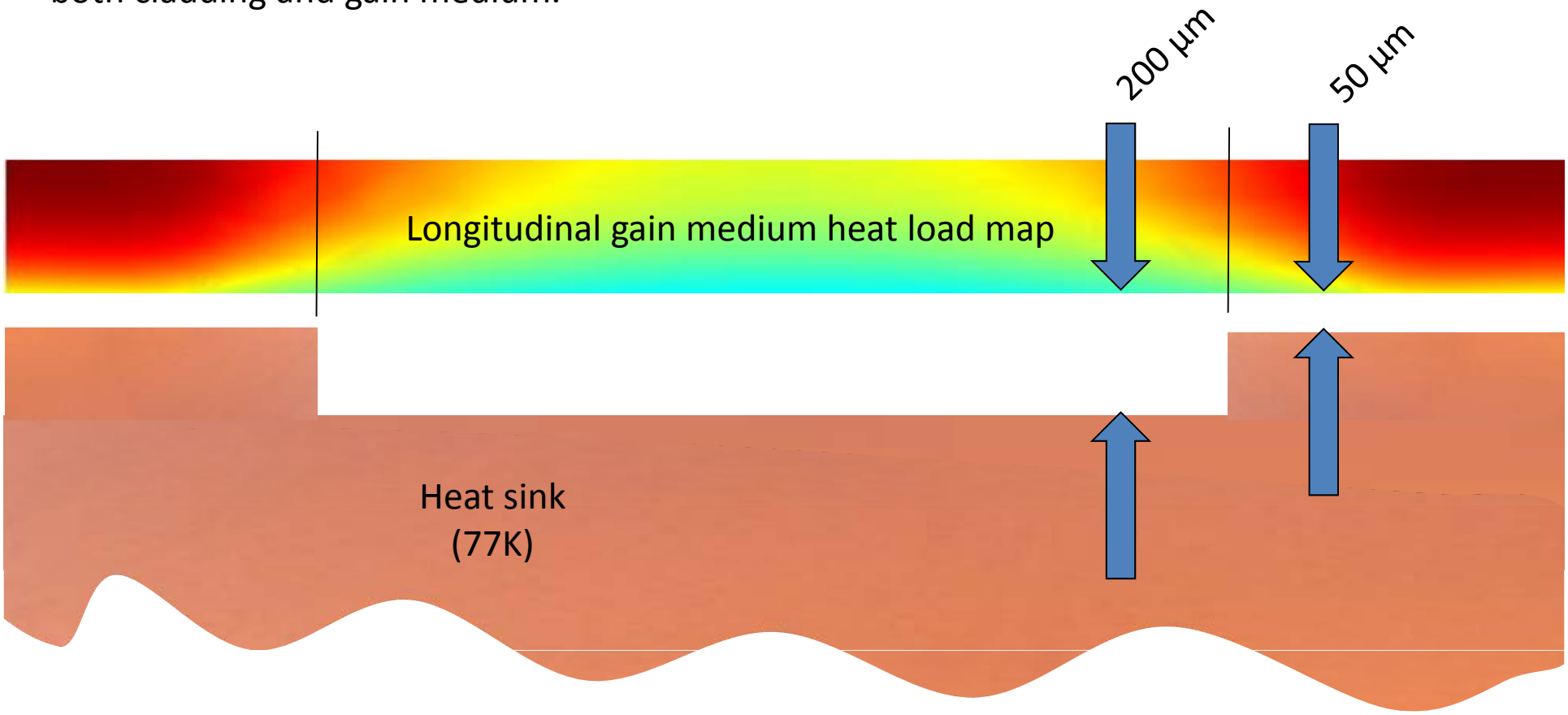
A 50 µm gap allows :

-cladding cooling with a pressure around 4.10^3 Pa

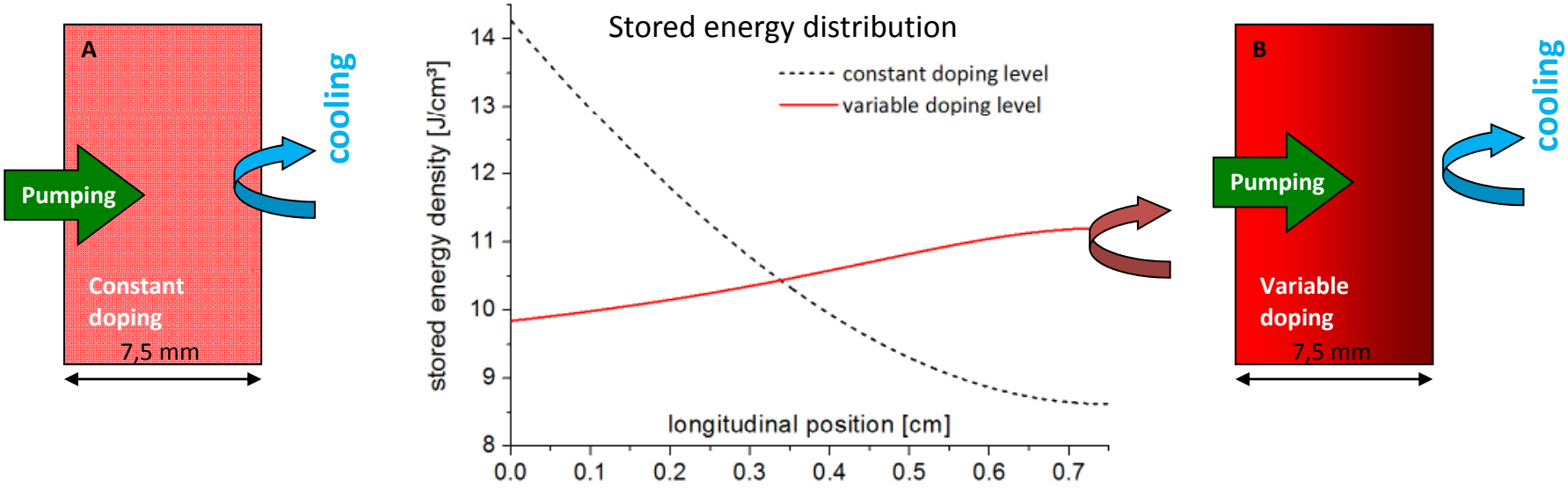
-gain medium with a pressure around 8.10^2 Pa.

Structuring the back surface

In practice, we propose to design a two steps level copper plate accommodating a single He pressure (for instance 4.10^3 Pa with 50 µm in front of the cladding and ~200µm in front of the gain medium).
Such structure would be required if we wish to end up with the same temperature for both cladding and gain medium.



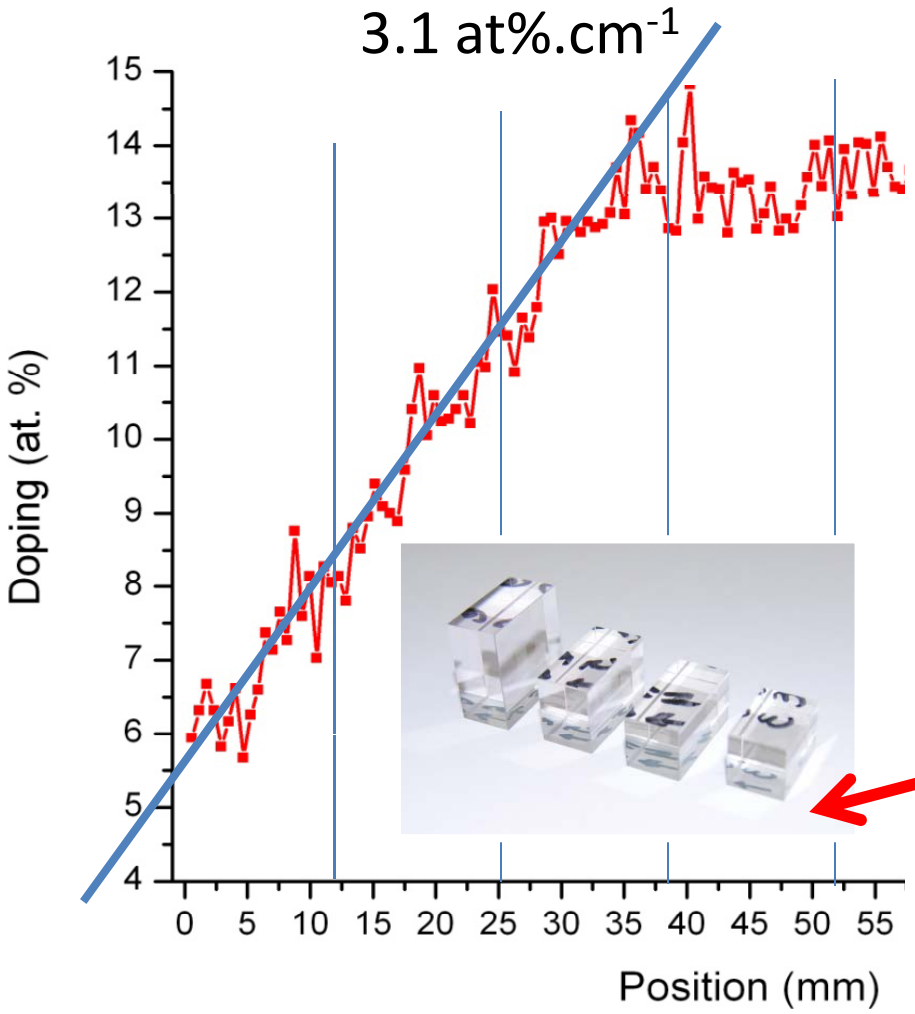
Gain medium engineering for ASE and thermal Manag^{t}



➔<u>Positive impacts expected on:</u>

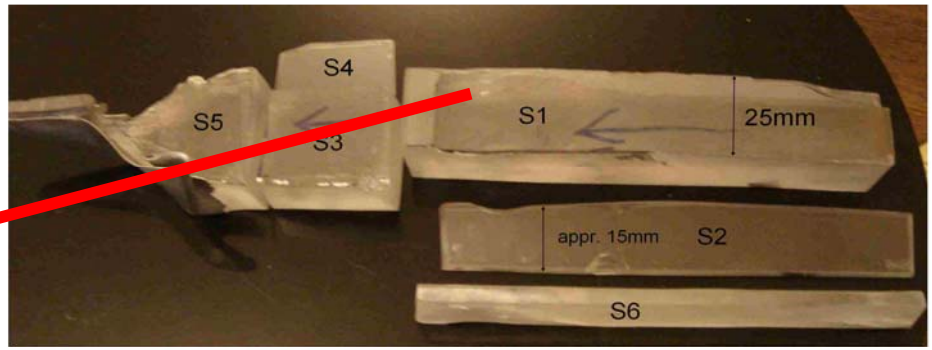
- Gain medium cooling ability (avoid energy concentration on non cooled side)
- ASE management (Stored energy density never exceed parasitics oscillations threshold)

Gain medium engineering :
3 at%.cm^{-1} Yb:YAG gradient boules

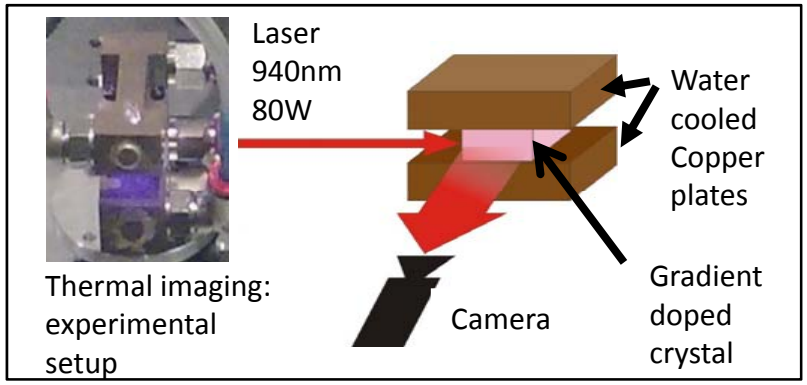


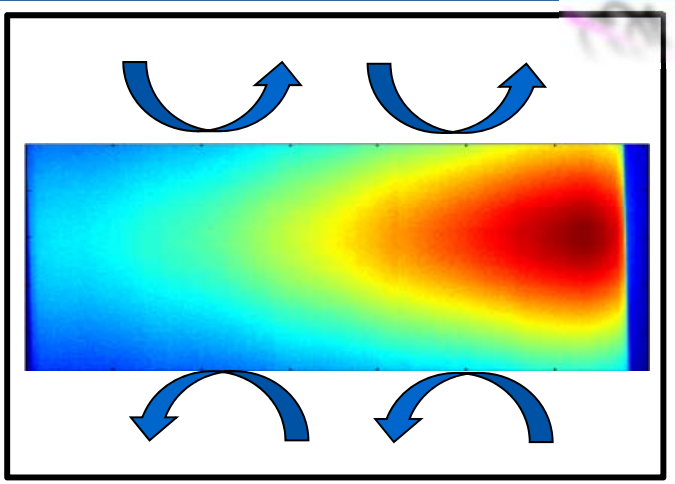
50 at%

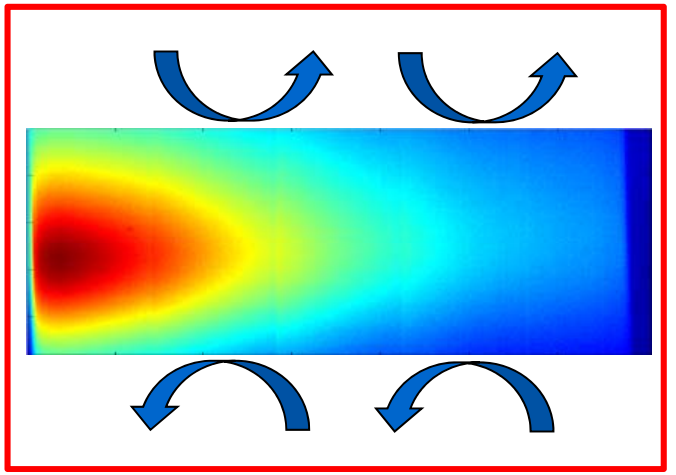
0 at%

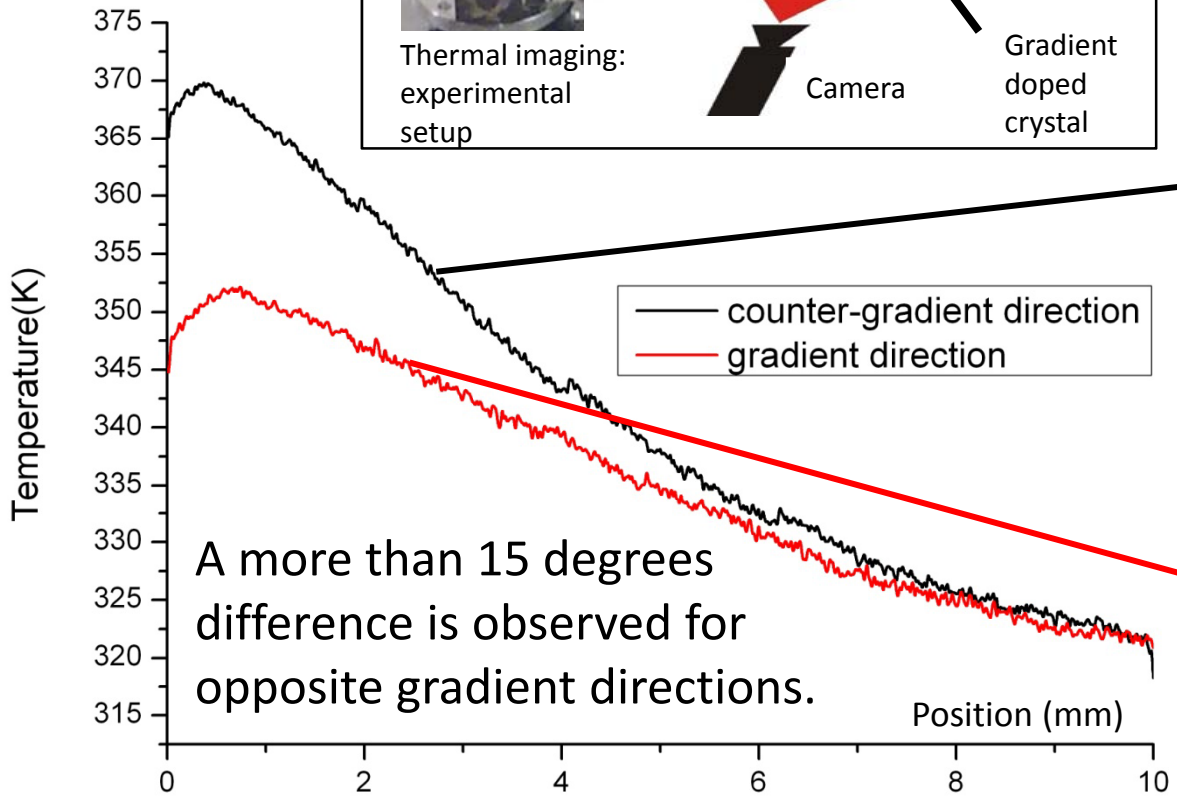


Thermal imaging clearly reveal gradient doping

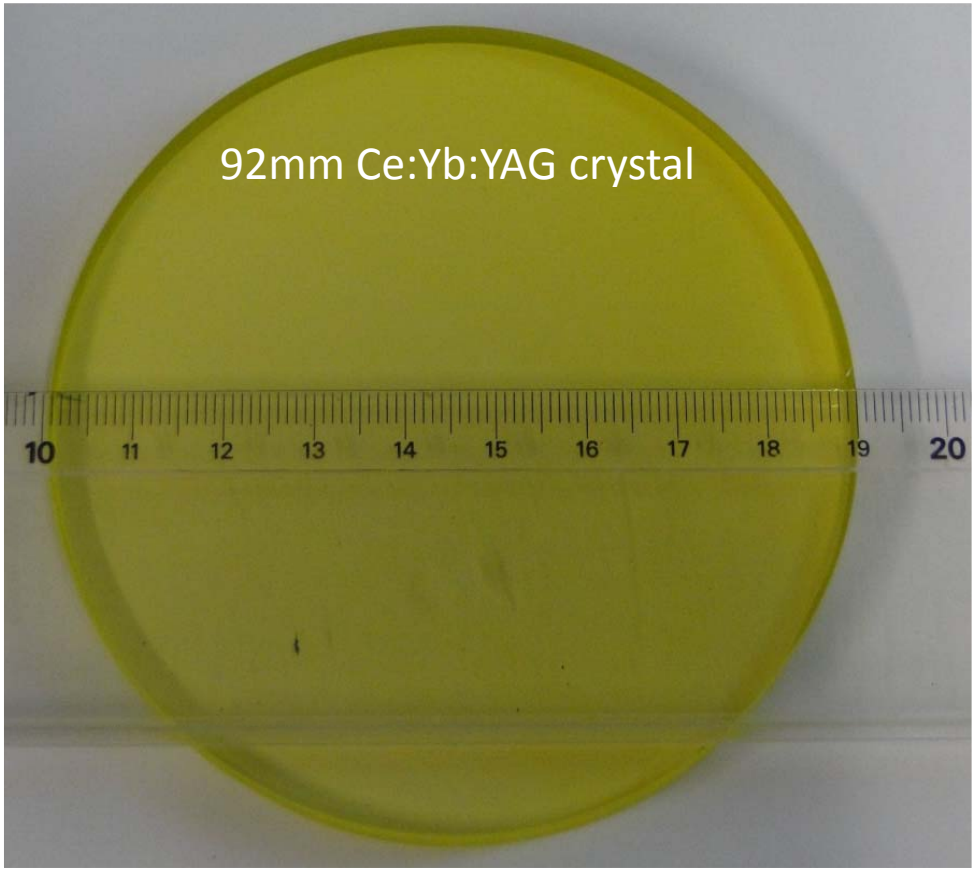




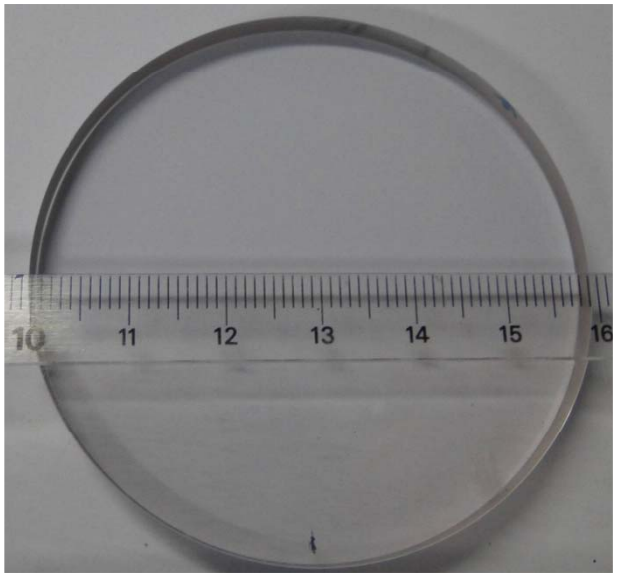


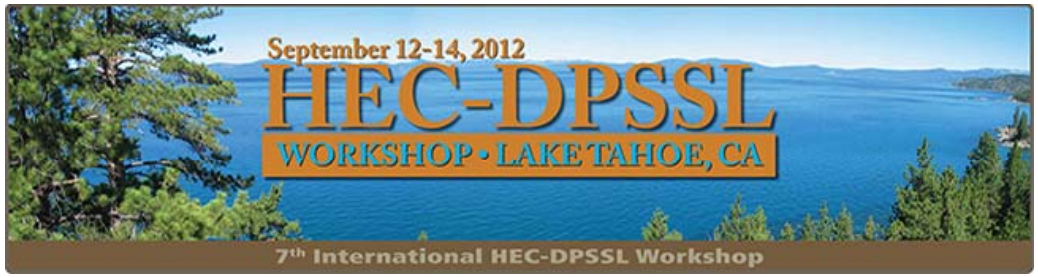


Large YAG crystals have been grown



60mm Yb:YAG crystal currently used in LUCIA main amplifier





Gradually Doped and Large Diameter Yb^{3+} Doped YAG Crystals for High Power Solid State Laser Applications

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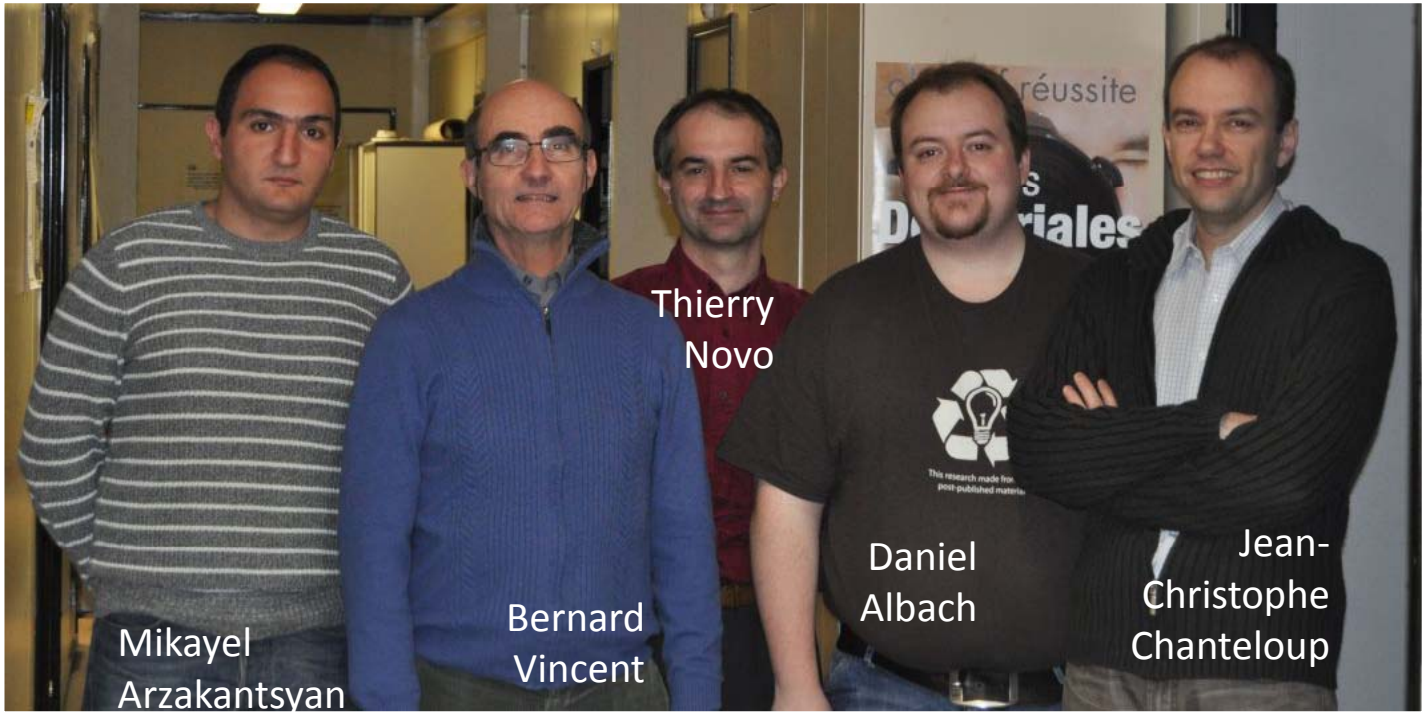
[2]Russian-Armenian (Slavonic) University, Yerevan, Armenia

[3]Laserayin Tekhnika CSC, Yerevan, Armenia

Thursday at 10:45 AM

The small (but great) Lucia team (80% here today)



Fluorescence measurements clearly reveal the gradient doping impact