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## LED pumped QCW Nd<sup>3+</sup>:YVO<sub>4</sub> laser

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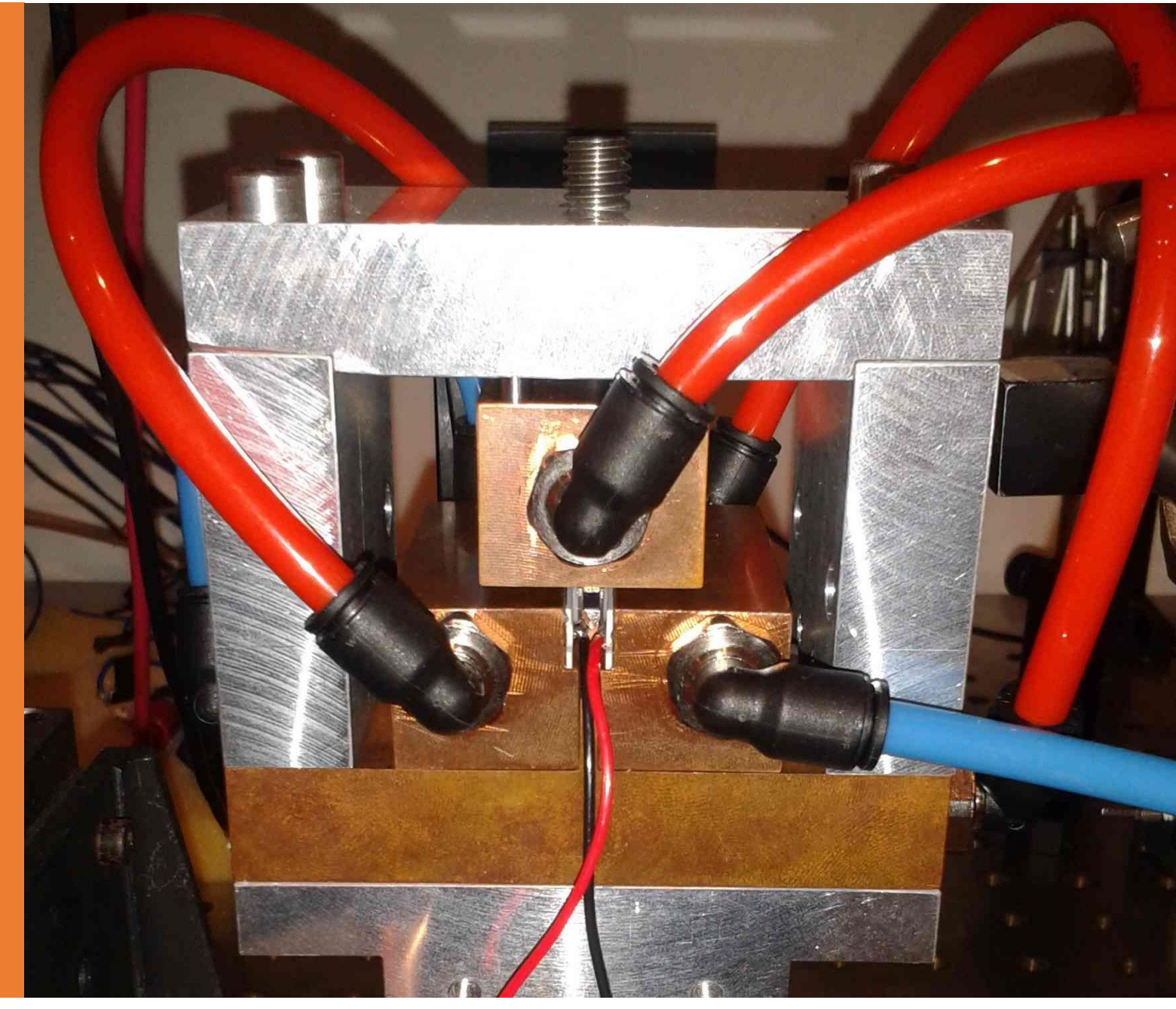
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# LED pumped QCW Nd<sup>3+</sup>:YVO<sub>4</sub> laser

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## Summary

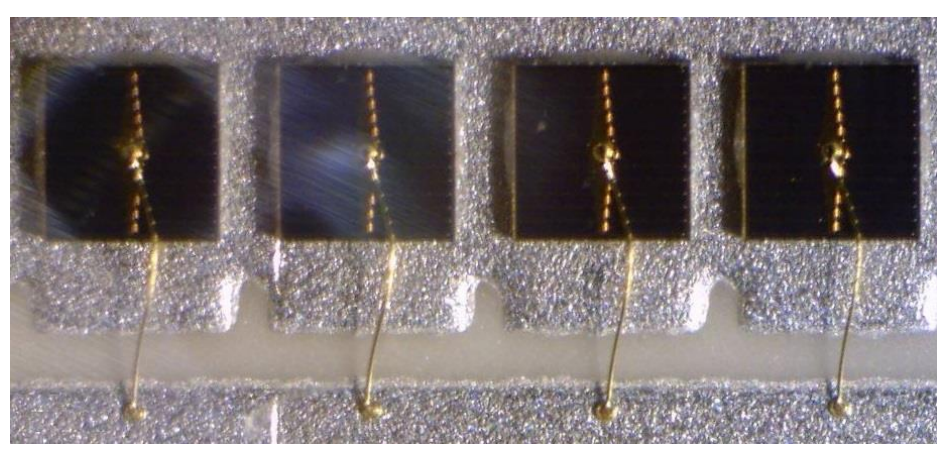
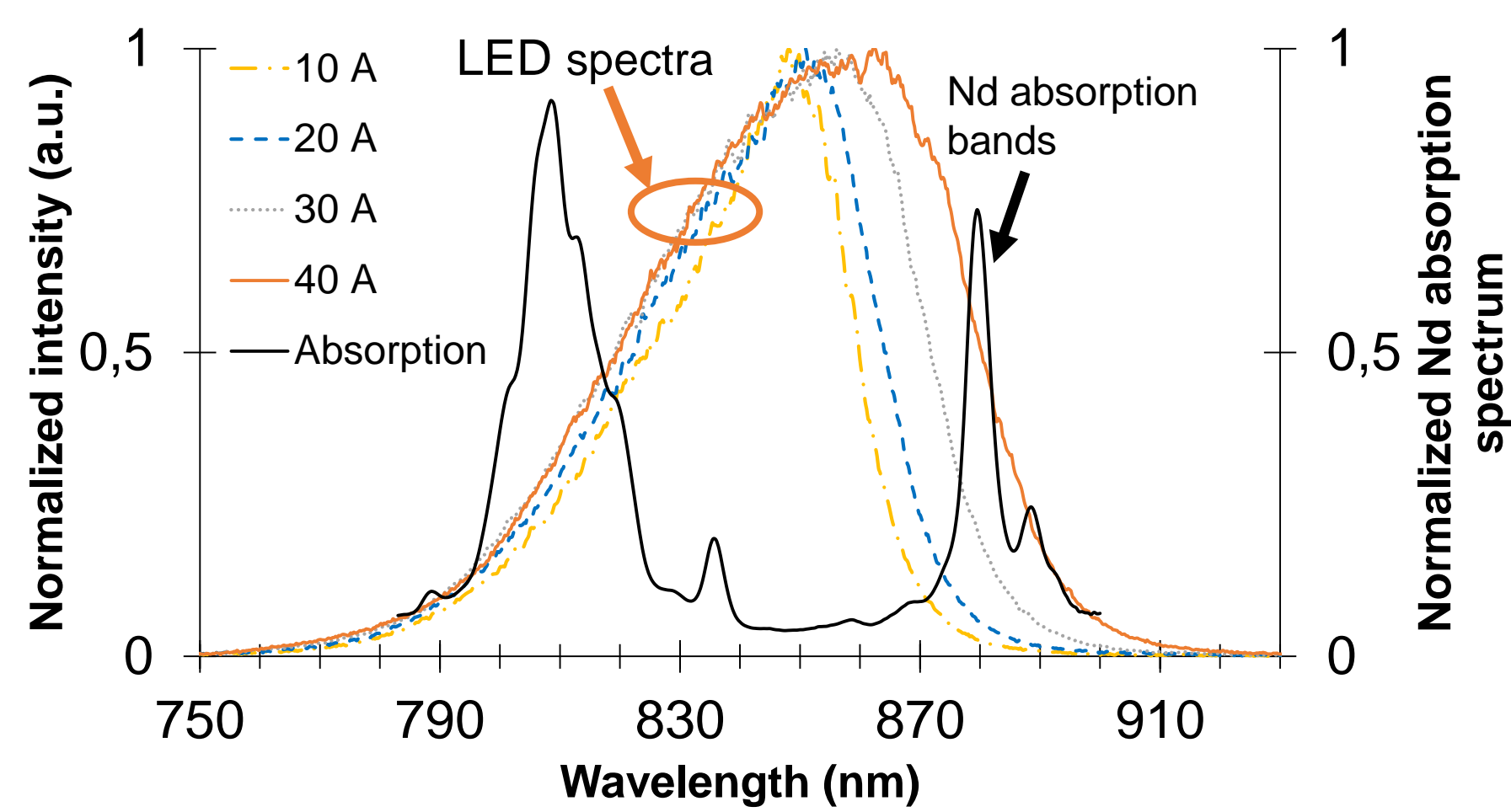
- ✓ Presentation of the **first LED pumped** Nd:YVO<sub>4</sub> laser
- ✓ Side pumping by 850 nm LED arrays
- ✓ At 250 Hz, E<sub>out</sub> = 40 μJ (at 1064 nm), E<sub>emitted</sub> = 7.4 mJ, η<sub>o/o</sub> = 0.5%

## Context

- ✓ 60-70's: LED pumping demonstration of Nd, Yb doped lasers [1]
- ✓ 2000's: lighting market → LED performance improved [2] + drop of LED price
- ✓ 2008: LED pumped polymer [3], fiber [4] and semiconductor [5] lasers have been demonstrated BUT bulk crystals not yet revisited

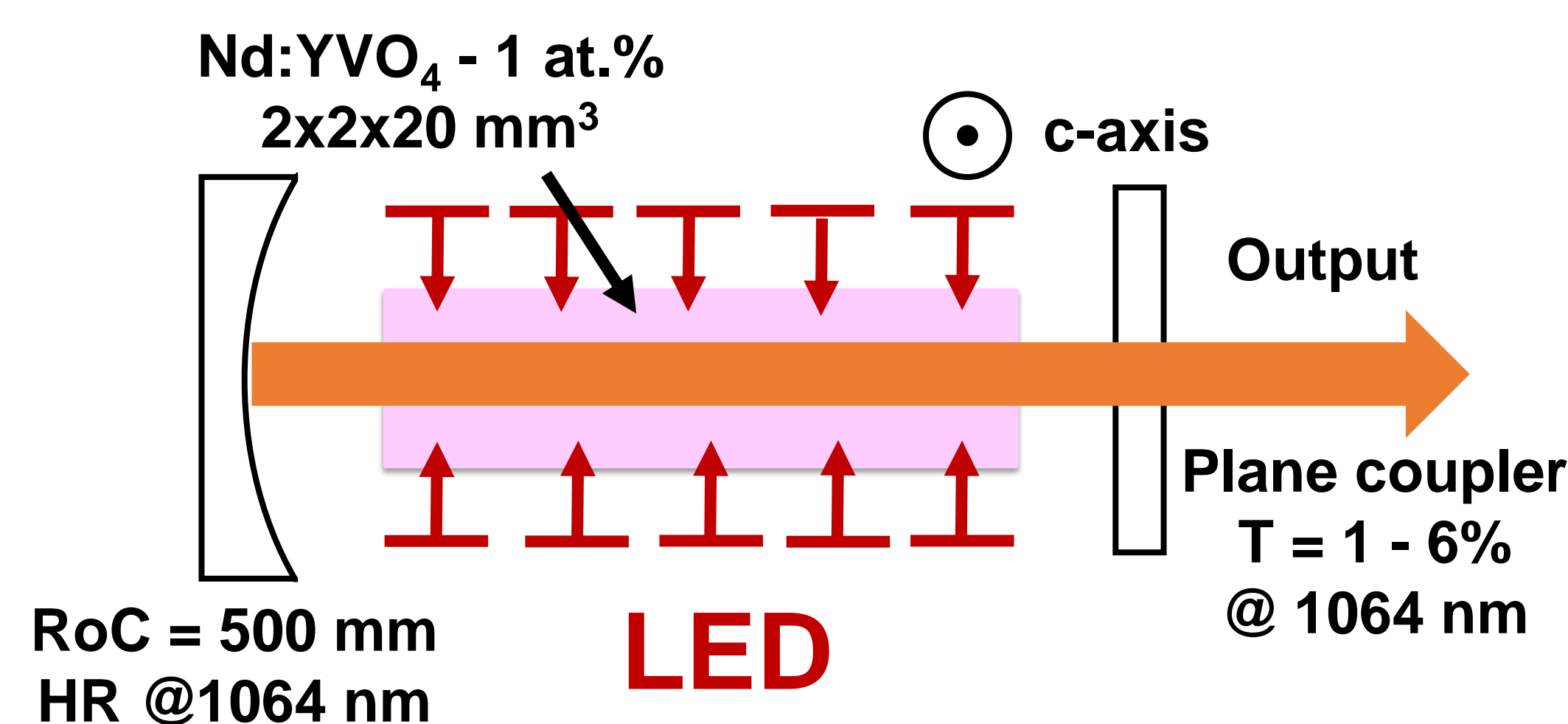
## Experiment results

### LED's characteristics



**LED array :**  
18 1x1 mm<sup>2</sup> dices, lambertian emission  
Intensity = 25 W/cm<sup>2</sup> (cw) → 200 W/cm<sup>2</sup> (pulsed)  
100 μs pulses, 250 Hz (damage above 400 Hz)

### Experimental setup



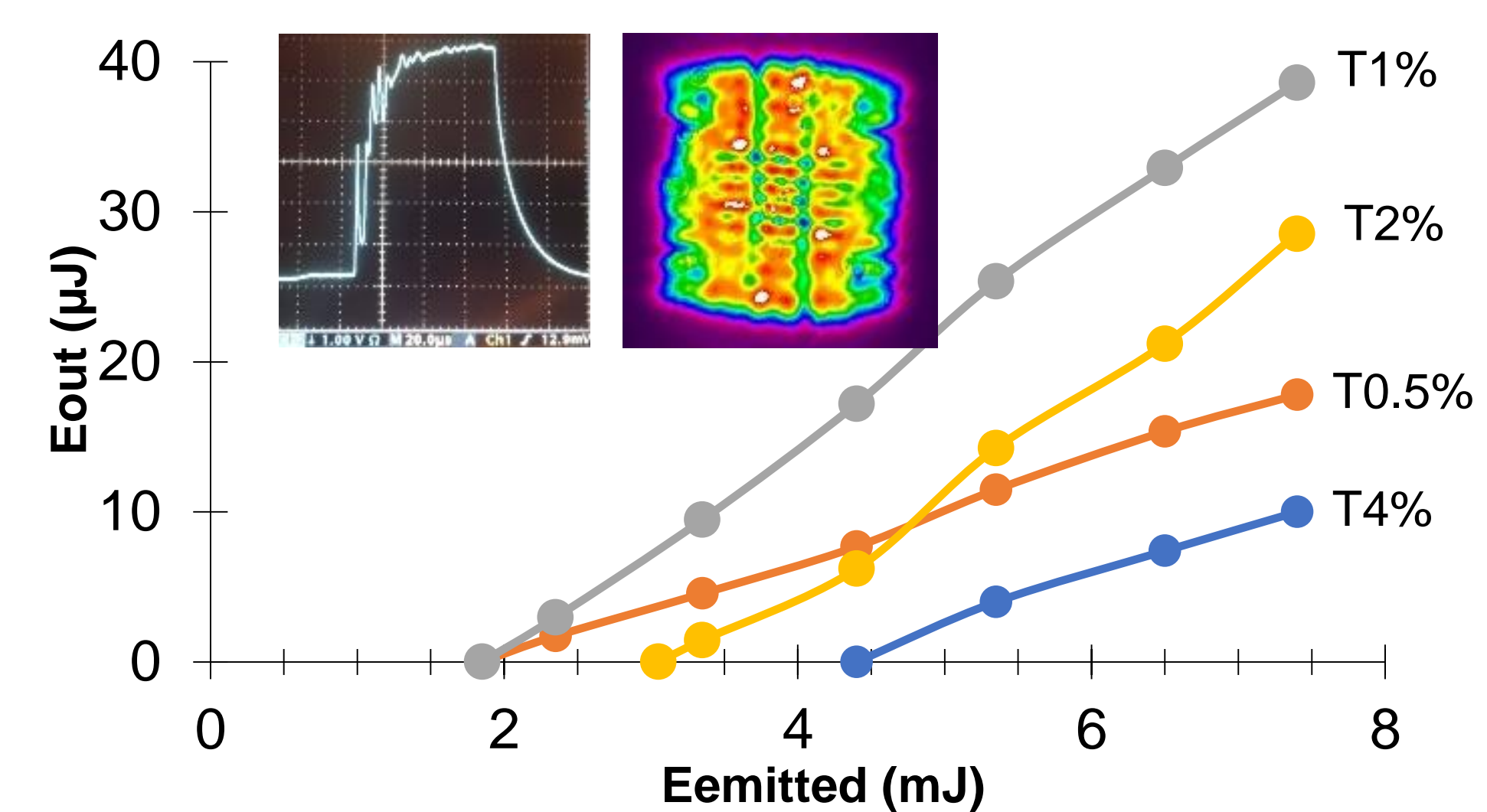
#### Nd:YVO<sub>4</sub> crystal :

2x2x20 mm<sup>3</sup>, 1% doped, water cooled  
AR coated @1064 nm laser facets  
2 transverse faces polished

#### Laser cavity :

Concave end mirror, R500 mm, HR@1064 nm  
Plane coupler, T = 1-6%  
L<sub>cav</sub> = 100 – 500 mm

### Laser results



#### Laser features :

Pulse duration = 65 μs  
Beam quality M<sup>2</sup> = 19  
E<sub>out</sub> = 40 μJ, E<sub>emitted</sub> by LED = 7.4 mJ → η<sub>o/o</sub> = 0.5%  
E<sub>absorbed</sub> = 1.5 mJ → η<sub>o/o</sub> = 2.6%  
Repetition rate = 250 Hz

## Small signal gain simulation using LightTools

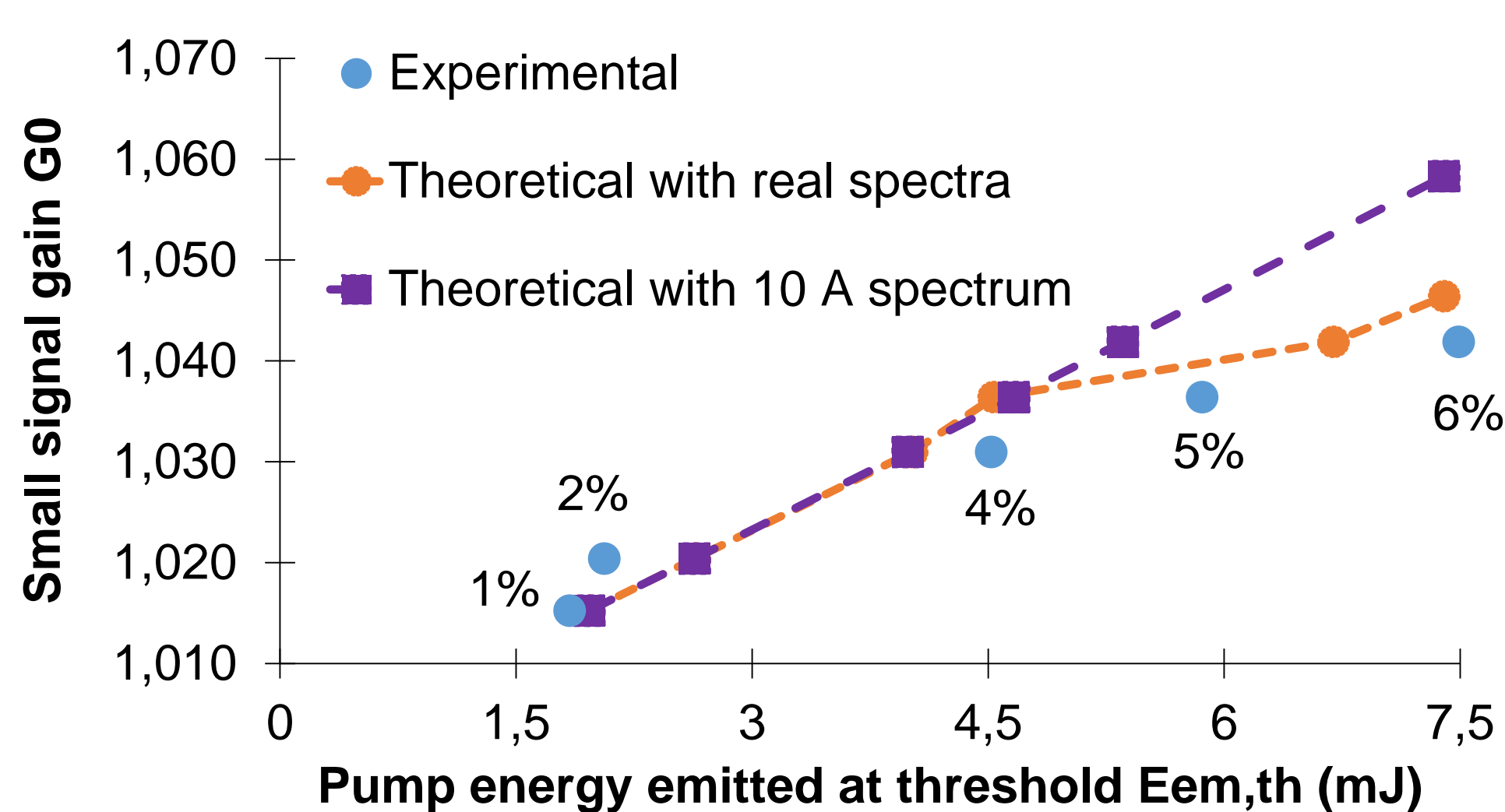
### Comparison theory / experiment

#### Calculations :

$$g = \frac{n_t \sigma_{el} \tau}{hc} \int_{\lambda_{p1}}^{\lambda_{p2}} \sigma_{ap}(\lambda_p) \lambda_p \frac{dI_p}{d\lambda_p} d\lambda_p$$

I<sub>p</sub> obtained from LightTools

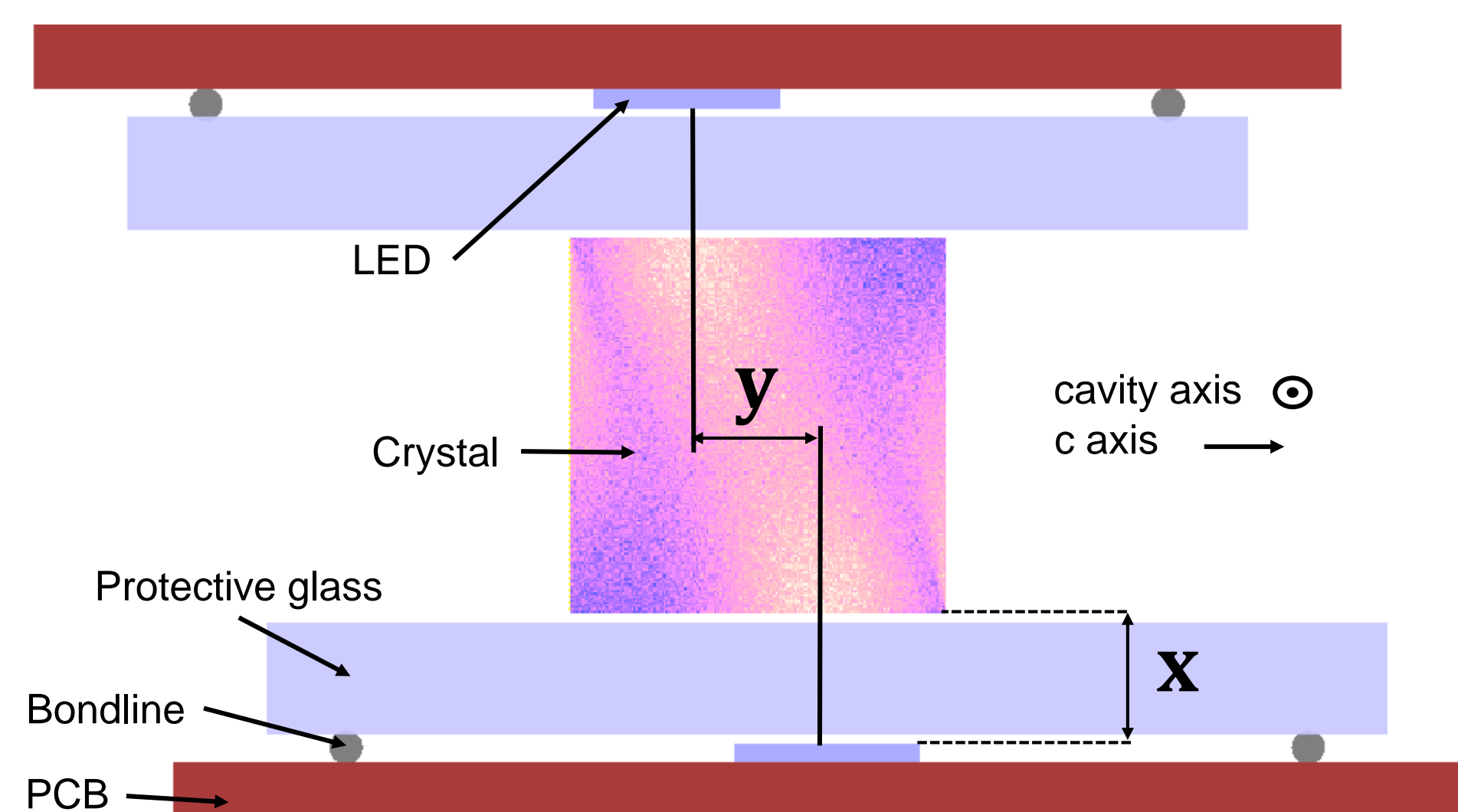
Spectral broadening with current = key parameter



### Pumping scheme

#### Simulation with LightTools :

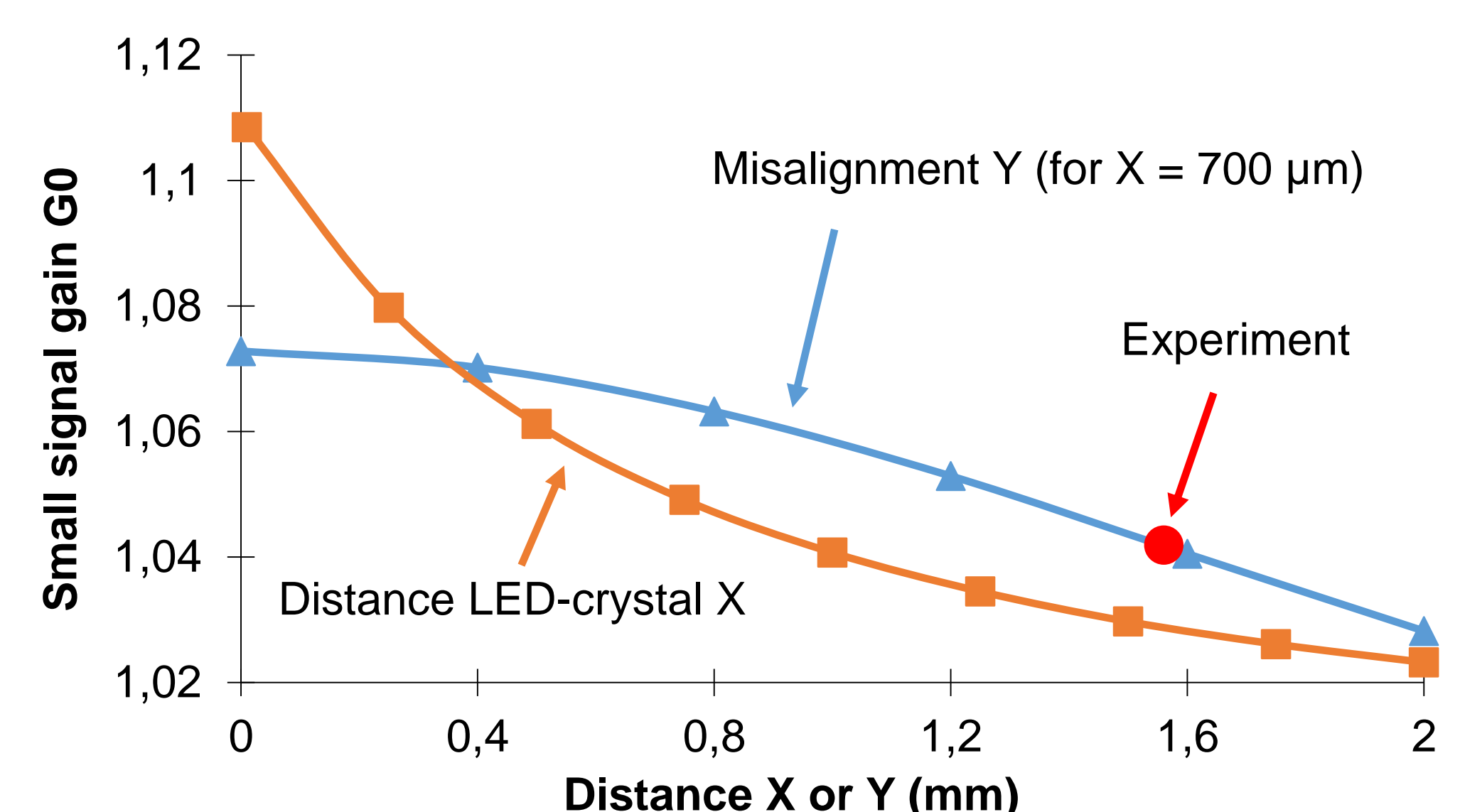
2 LED arrays : geometry, spectrum, position, power...  
Crystal : refractive index, absorption spectrum...  
Tens millions of rays → Residual pump intensity I<sub>p</sub>



### Effect of the misalignment

#### Two spatial influent parameters :

Misalignment between the two LEDs Y  
Distance LED-crystal X (working distance = 700 μm)  
→ Strong effect of the distance X



## References

1. R. B. Allen & S. J. Scalise, *Appl. Phys. Lett.* **14**, 188 (1969).
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  3. Y. Yang, G. a. Turnbull, and I. D. W. Samuel, *Appl. Phys. Lett.* **92**, 163306 (2008).
  4. L. Htein, W. Fan, P. R. Watekar, and W.-T. Han, *Opt. Lett.* **37**, 4853 (2012).
  5. X. Liu, G. Zhao, Y. Zhang, and D. G. Deppe, *Appl. Phys. Lett.* **102**, 081116 (2013).
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## Perspectives

- ✓ Improve efficiency by using new LEDs (blue chip with phosphor, double stack chip)
- ✓ Tests of other Nd doped crystals (such as Nd:YAG or Nd/Cr:YAG)
- ✓ LED pumping potentially represents a intermediate between DL and flash pumping