

Shaping the Future of High-Power UV-Visible Lasers Through Advanced Pulsed and Nonlinear Technologies

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DE LA RECHERCHE
ET DE L'INNOVATION



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Content

1. Who we are ?
2. Photonics for Defense in ALPhANOV
3. High average power visible laser development
 - 3.1 In Pulsed regime with BLOOM LASER
 - 3.2 In CW regime
4. Conclusions

AN



ESTER Technopole Limoges-FRANCE

PYLA
CENTRE DE FORMATION



Laser & Components



Laser processing



Photonics Systems



IC testing

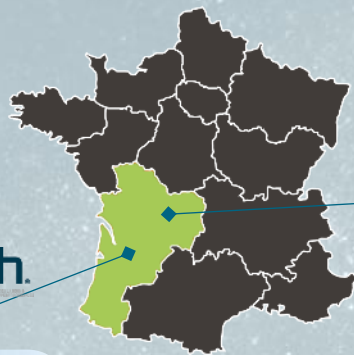


Training Center

INSTITUT d'OPTIQUE GRADUATE SCHOOL

PYLA

ALPHARh



Institut Optique d'Aquitaine Talence - FRANCE

2007

Foundation

+ 110

Employees

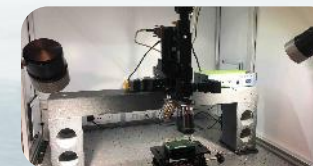
20+

Running collaborative projects

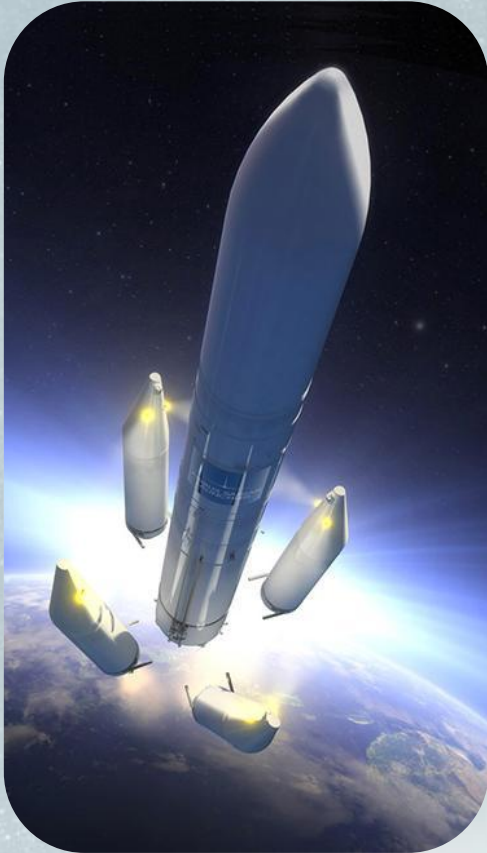
(supported by the European Union, the state, national organism and the Nouvelle-Aquitaine Region)

ALPhA NOV

Optics & Lasers Technology Center



... serving 4 Strategic Application Areas



**Aerospace, Defense
& Security**



**Industry of
the future**



**Biotechnologies,
Pharmaceuticals
and Health**



**Sustainable
development**



ALPhANOV, Your Photonics Partner for ASD applications





Optoelectronic devices

- ✓ Optoelectronics conception
 - ✓ Laser diode drivers
 - ✓ Opto pyrotechnology



- ✓ Hard environment qualification
 - ✓ Optical testing
 - ✓ Vibration pot
 - ✓ Environmental chamber





Vulnerability Test Facility

- ✓ Joint lab with **MBDA**
- ✓ 10 kW class IR fiber laser
- ✓ Thermometry analysis
- ✓ Material damaged threshold studies under stressed conditions



OPTOELECTRONIC DEVICES: DESIGN & QUALIFICATION 

LASER-MATTER INTERACTION STUDIES 

INTEGRATED CIRCUITS & DETECTORS TESTING 

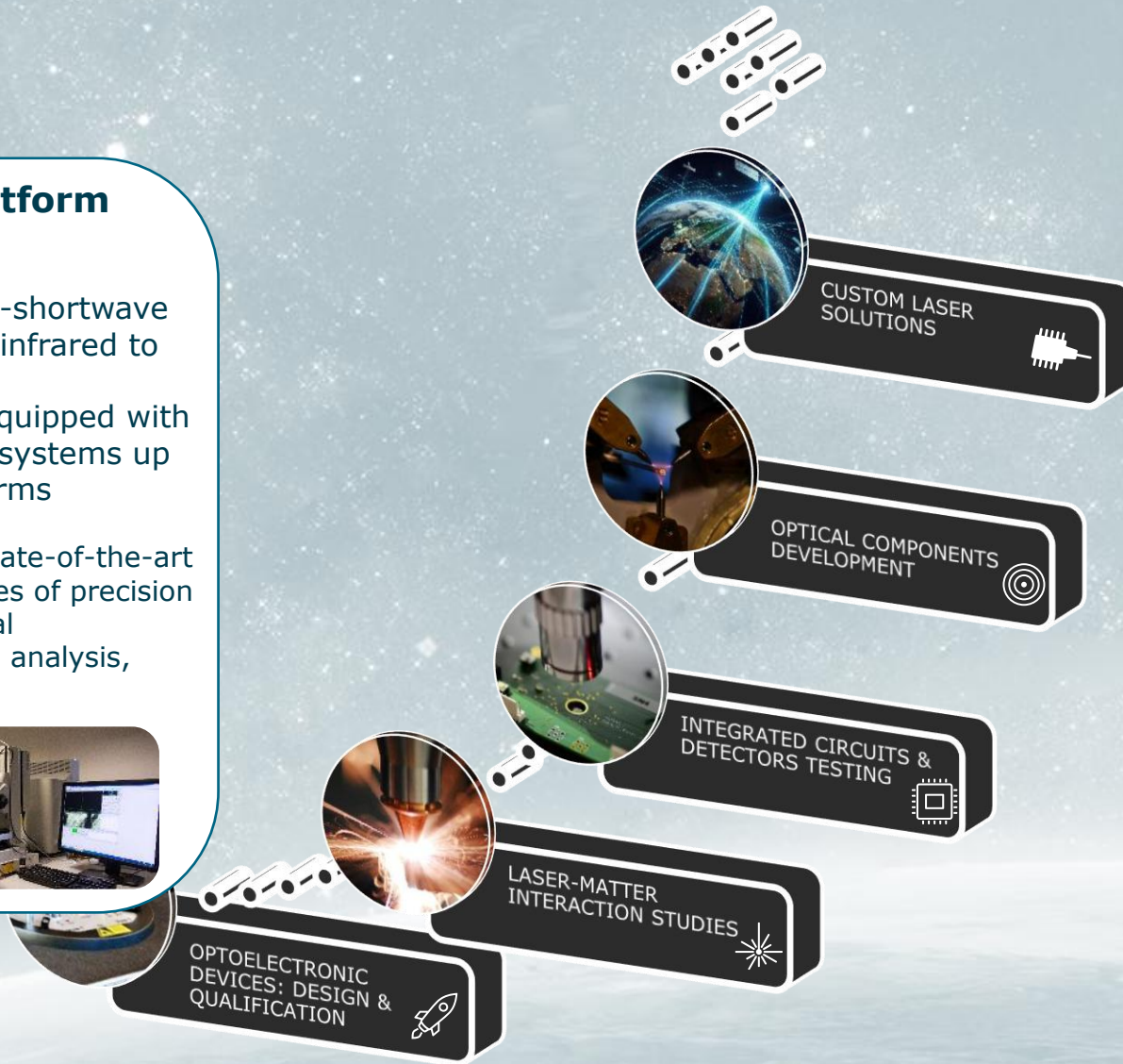
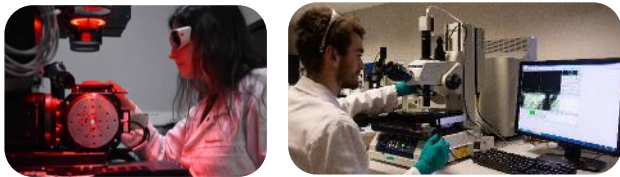
OPTICAL COMPONENTS DEVELOPMENT 

CUSTOM LASER SOLUTIONS 



Laser processing platform

- ✓ > 20 sources
- ✓ from continuous to ultra-shortwave (femtosecond) emitting infrared to ultra-violet light
- ✓ 15 machining stations equipped with micrometric positioning systems up to 5 axes or robotized arms
- ✓ Metrology platform with state-of-the-art equipment for various types of precision analysis (SEM, AFM, optical profilometer, metallurgical analysis, measuring microscope).



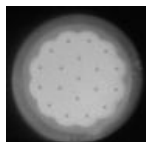
Failure IC and sensor analysis

- ✓ IC testing and vulnerability
- ✓ Laser dazzling
- ✓ Fault injection



Optical components development

- ✓ PCF- Fiber functionalisation
- ✓ Fiber beam delivery : LMA fibres and dedicated connectors with mode strippers
- ✓ Photonic Lantern for optical communication
- ✓ Femtosecond inscription platform



OPTOELECTRONIC DEVICES: DESIGN & QUALIFICATION



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OPTICAL COMPONENTS DEVELOPMENT



CUSTOM LASER SOLUTIONS



CUSTOM LASER SOLUTION

- ✓ Fiber based laser development
 - ✓ LMA doped fibers : Er, Tm, Yb
 - ✓ Single frequency regime to ultrafast pulsed regime
- ✓ Applications to SLR, LIDAR, ...



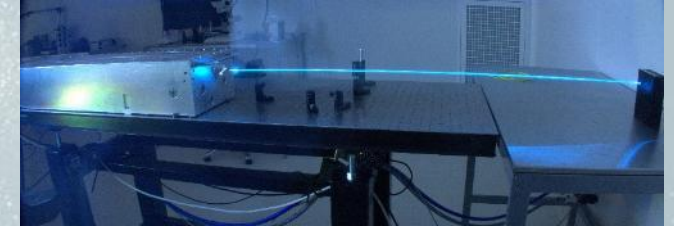
- High average power laser in the visible-UV requires :
 - High average power in the infrared region
 - High repetition rate,
 - High peak power to have an efficient frequency conversion
 - Short pulse duration and a trade-off with the spectral bandwidth acceptance
 - Robust frequency conversion module
 - Optimised non-linear crystal, oven, mechanical stability
- For what ?
 - Micromachining
 - Semiconductor industry

 - Defense
 - Quantum application
 - ...

- In Pulsed-Regime : collaborative development with BLOOM Laser, high power green and UV light in the picosecond regime



Based in Pessac, France
20 employees
150 m² ISO6 clean room



Industrial laser sources
nanosecond /picosecond
GREEN and **UV**



>30,000 hours UV lifetime
100W UV power
Excellent beam quality

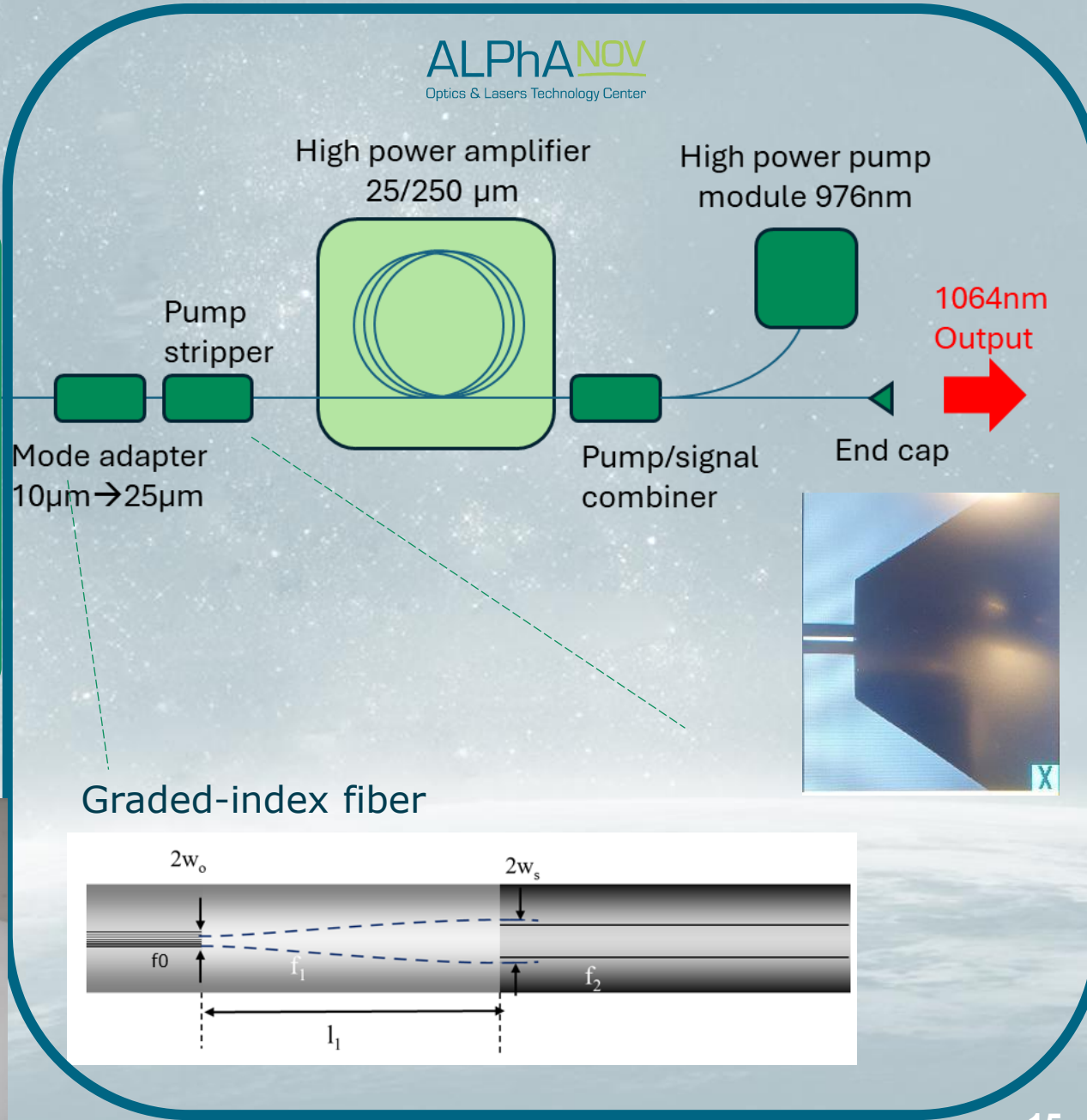
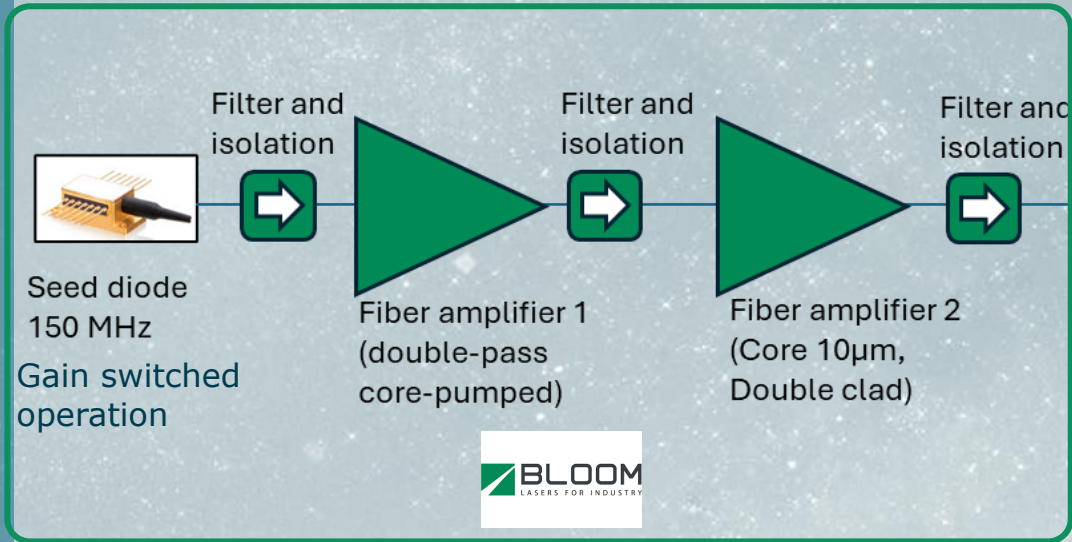


Focused on reliability (HALT/HASS)
>15 years of laser design experience
>150 lasers per year production capabilities

Our objective:

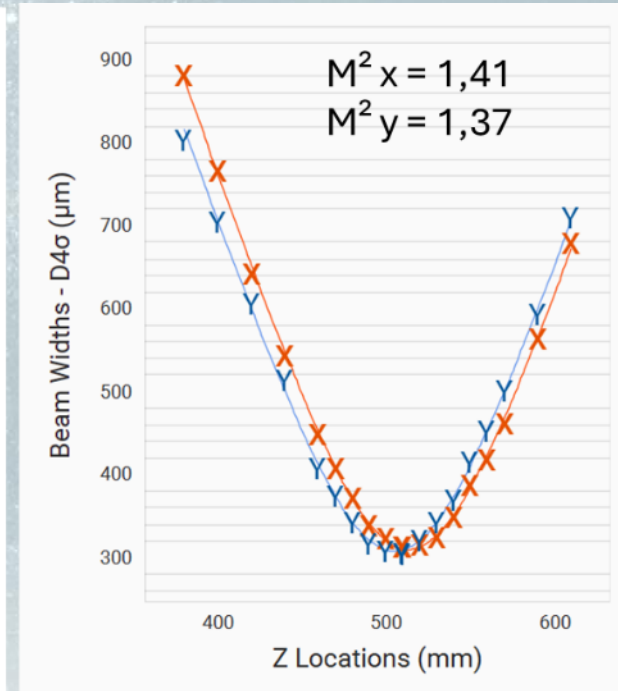
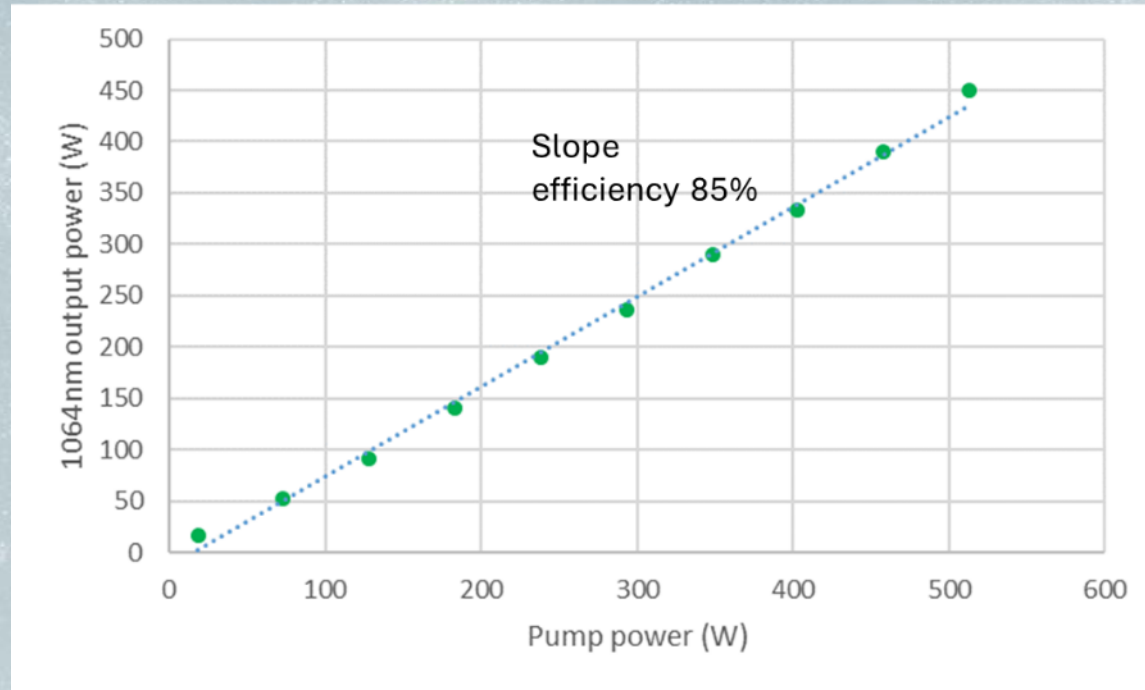
- **355nm, >100 W average power, >30 MHz, < 15kW peak power, $M^2 \sim 1$**
- Pulse duration must be **200 ps – 1ns**
- Need **MOPA IR laser + conversion module IR→UV**
- Low peak power → limited UV conversion efficiency with standard non-linear crystals
- ✓ → **Need high IR average power** ($\sim 350-450 W @ 1064nm$)
- ✓ Need long non-linear crystals (**$\sim 40mm$**)
 - **IR spectrum must be narrow enough** ($\sim 300pm$)
 - Need to manage walk-off effect
- ✓ Need good UV beam quality → Need good IR beam quality → **Fiber amplifiers**
- ✓ Need to generate pulses at $>30MHz$, $> 200ps$, narrow spectrum → **Gain-switched DFB diodes**

Experimental setup : IR MOPA





Results : IR MOPA

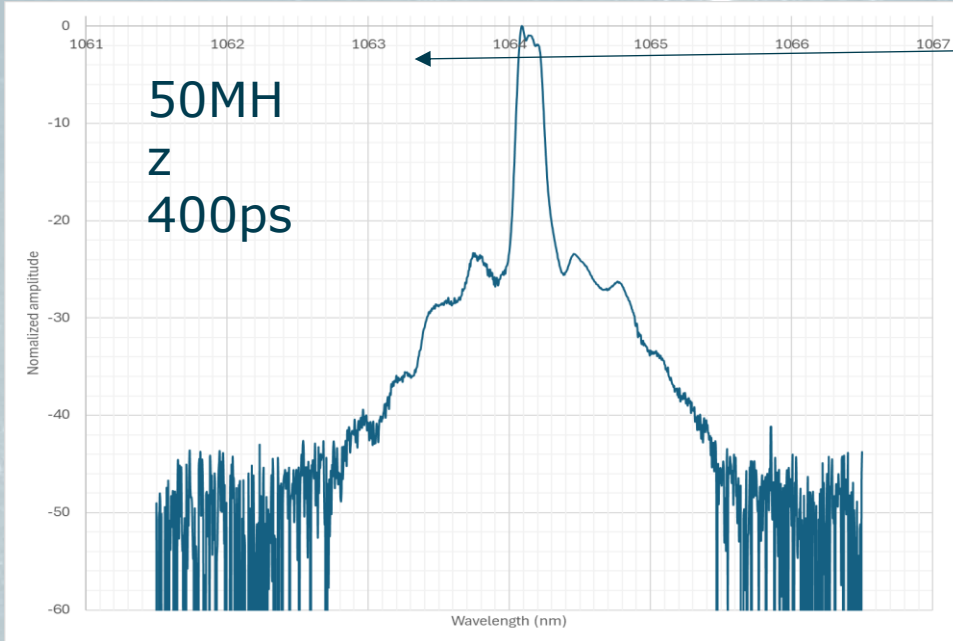


1064nm, 30-50MHz , 300 400ps
450W output power
 $M^2 \sim 1,4$

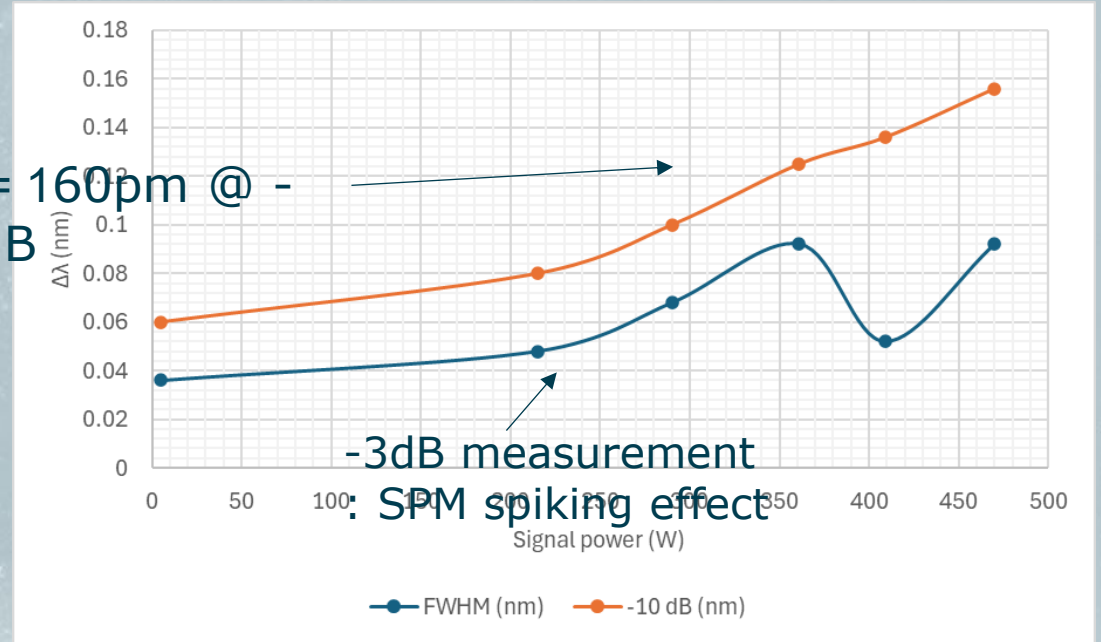




Results : IR MOPA



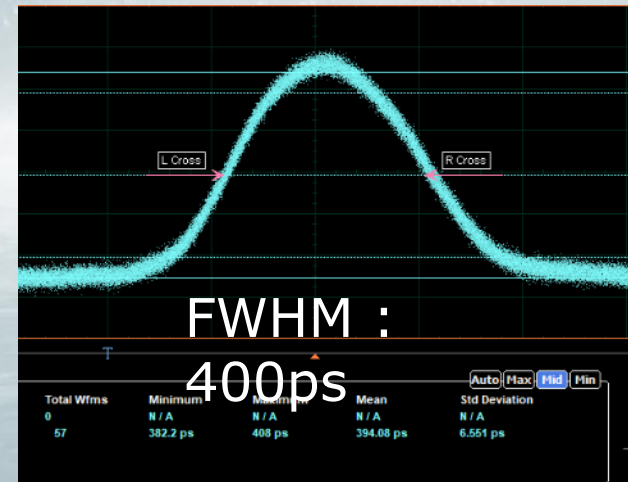
$\Delta\lambda = 160\text{pm} @ -10\text{dB}$



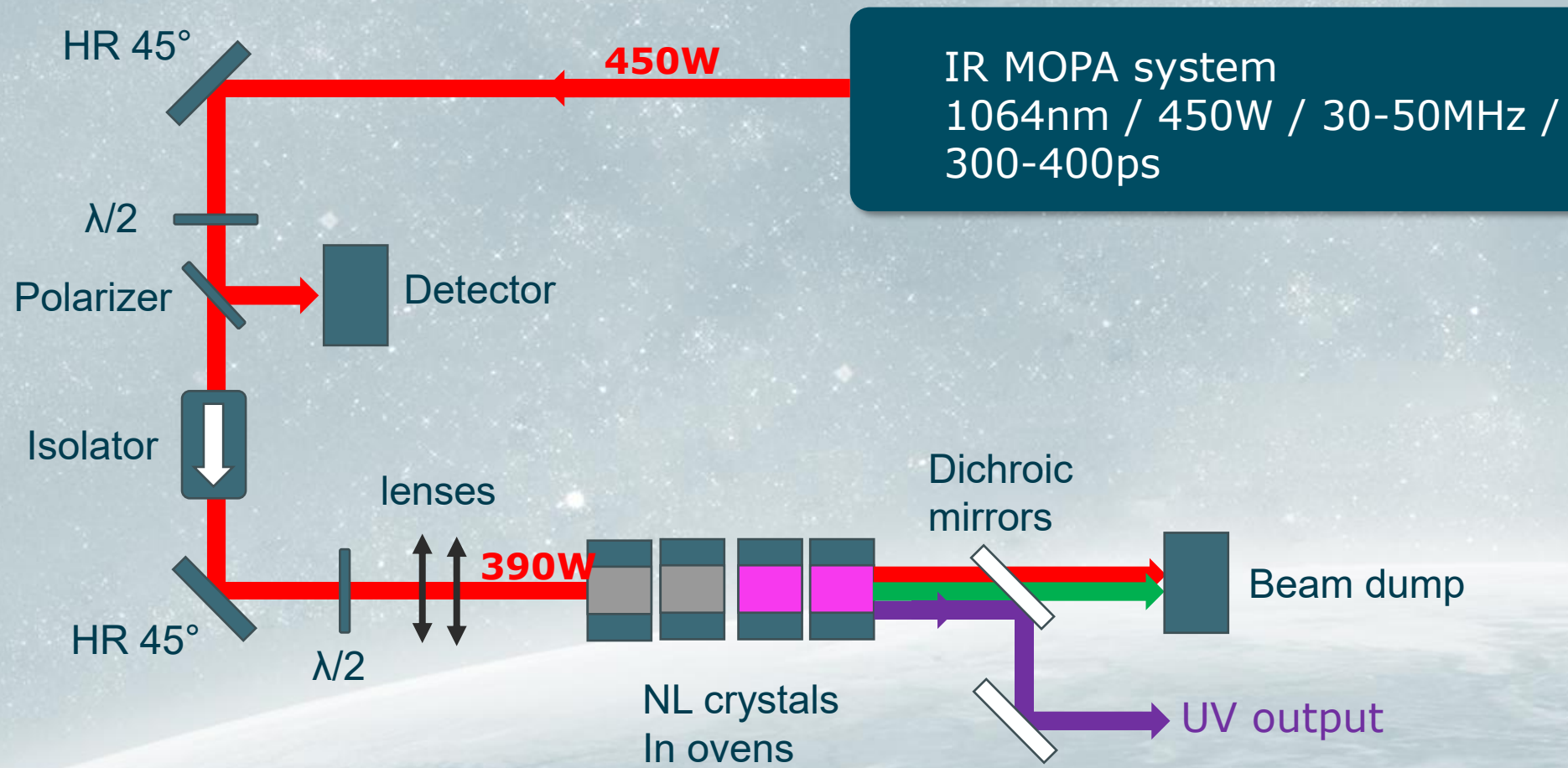
➔ Effect of Self-Phase modulation (SPM) clearly visible

Spectral bandwidth evolution with parameters (-10dB) :

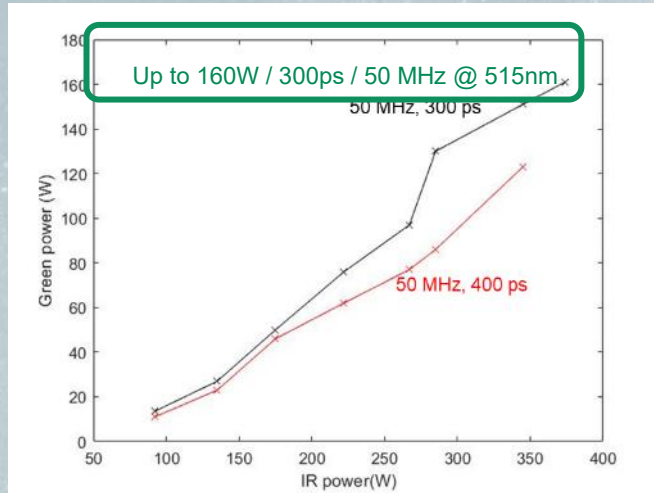
- 160pm @ 50MHz / 400ps
- 320pm @ 50MHz / 300ps



Experimental setup : UV frequency conversion



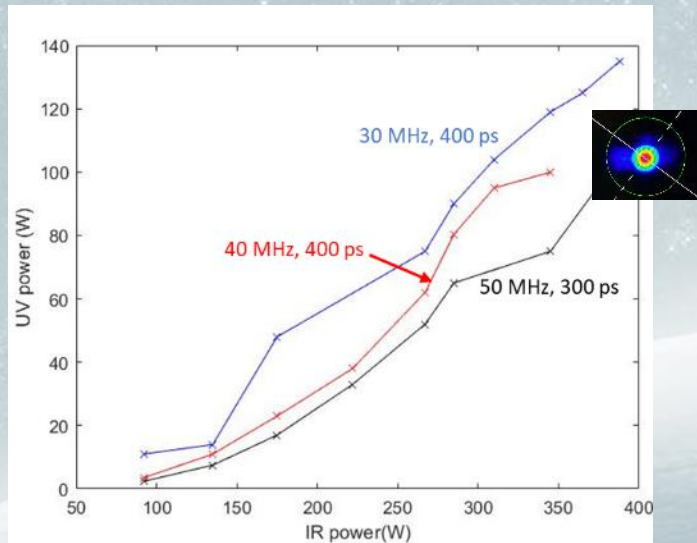
Results: Green & UV conversion



Generation of 532 nm :

- Two LBO crystals in WO compensation (Type 1 SHG)
- Tuning pulse duration 300-400 ps
- Conversion efficiencies :
 - 34% at 400ps (simulated : 38%)
 - 44% at 300ps (simulated : 46%)

Good agreement with simulations



Starting point at 370W IR / 50MHz/300ps

- ➔ 90W UV output (from 160W green + 210W IR)
- ➔ 24% Efficiency (simulated : 32%)

To get > 100W UV :

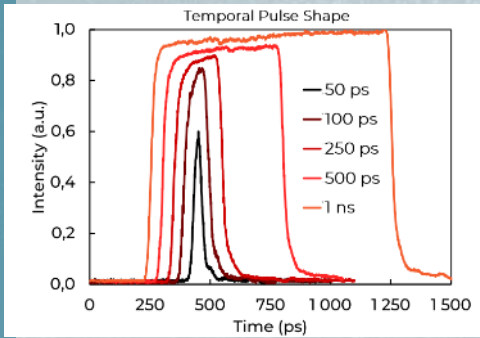
- ➔ Need to increase the IR average/peak power
- ➔ But limitation due to spectral acceptance of SFG stage

Best result at 390W / 30MHz / 400ps :

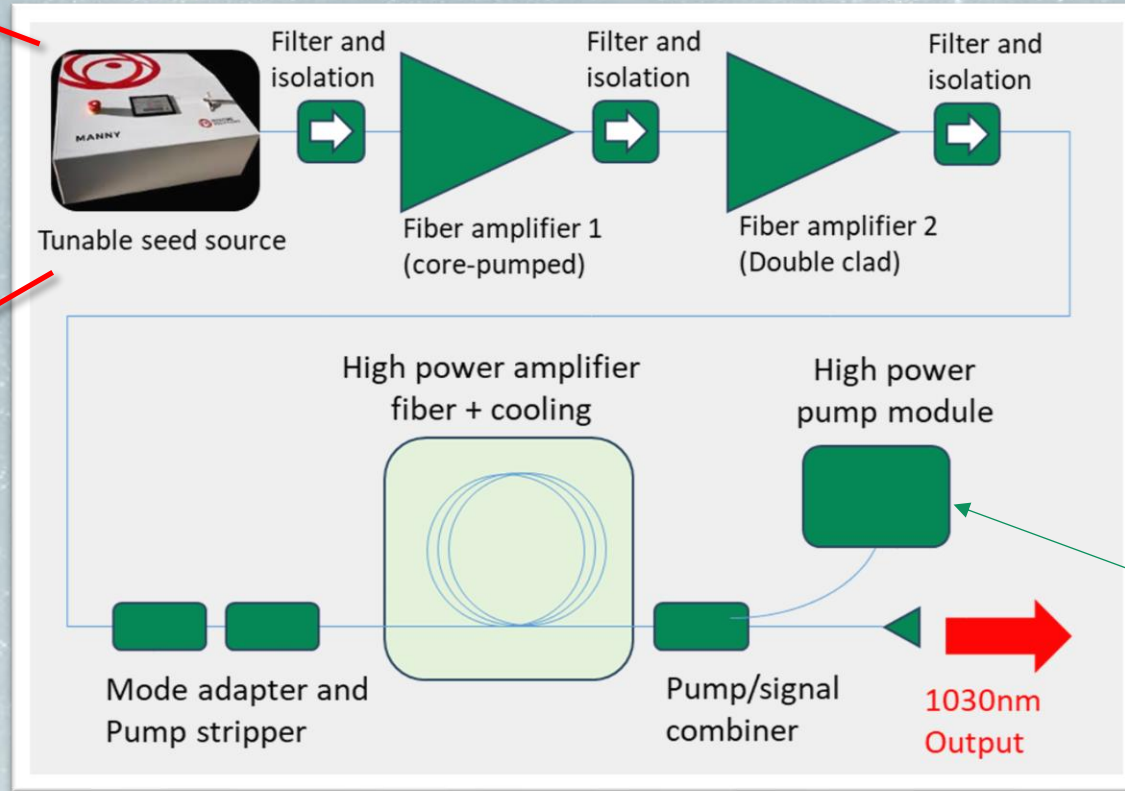
- ➔ 135W UV output (35% efficiency)



How to go get more average power ?



100-1000 ps continuously adjustable @ 1030 nm



Pump power scaling

High power fiber amplifier optimization

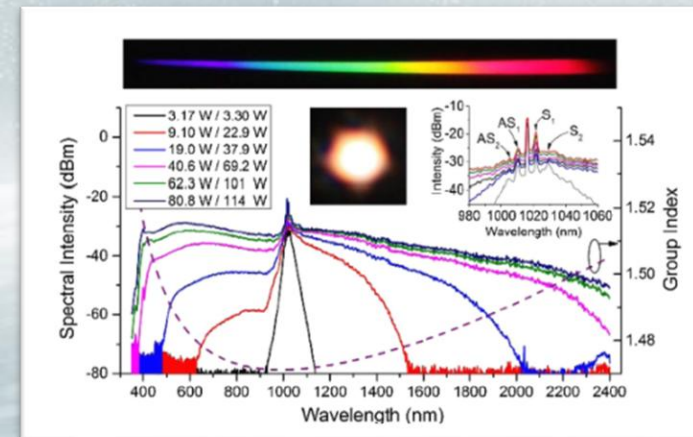
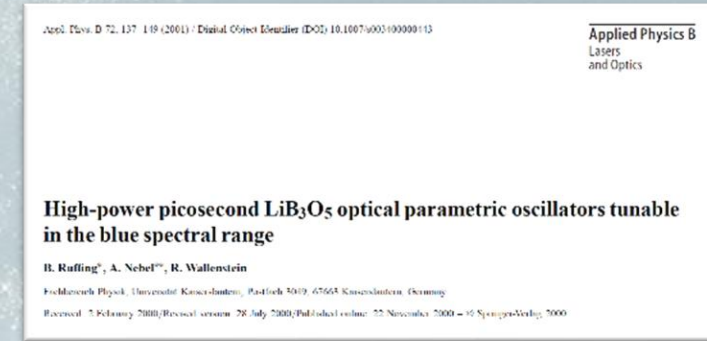
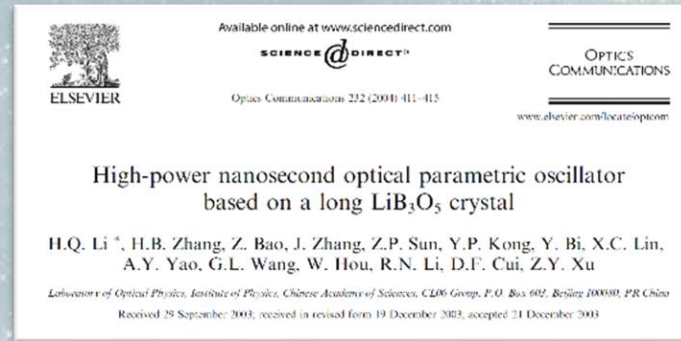
Undergoing work...

Opportunity to collaborate ?!

➤ Ideal driver for high power widely tunable source in the VIS/NIR/SWIR

- ✓ sub-ns based OPO
 - ✓ Pumped in Green or UV
- 20-30% conversion efficiency

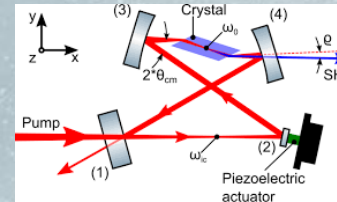
➤ Potential for high power (100W+ class) supercontinuum source in the VIS/NIR/SWIR





SHG conversion in CW operation

- For quantum applications, laser operates in a CW regime with a single frequency source
- Visible light is possible by using frequency conversion in a external cavity with appropriate non-linear crystal

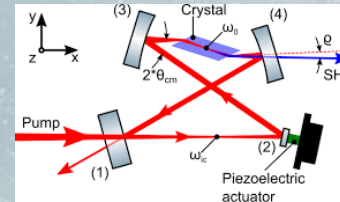


Parameters	ppsLT	ppKTP	BiBO	BBO	LBO
Phase Matching	Quasi-phase matching Type 1	Quasi-phase matching Type 1	Critical phase matching	Critical phase matching	Critical phase matching
d_{eff} (pm/V)	5	10.8	3.42	2	0.8
Walk-off (angle/mrad)	0	0	44.5	61.34	9.38
Transparent Range (nm)	300-5000	350-4500	286-2500	185-2600	160-2600
Thermal effects	YES	YES	NO	NO	NO



SHG conversion in CW operation

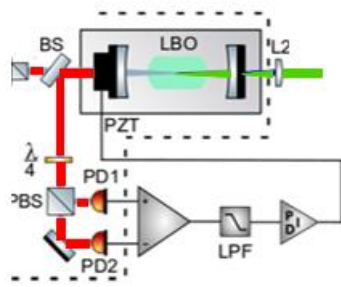
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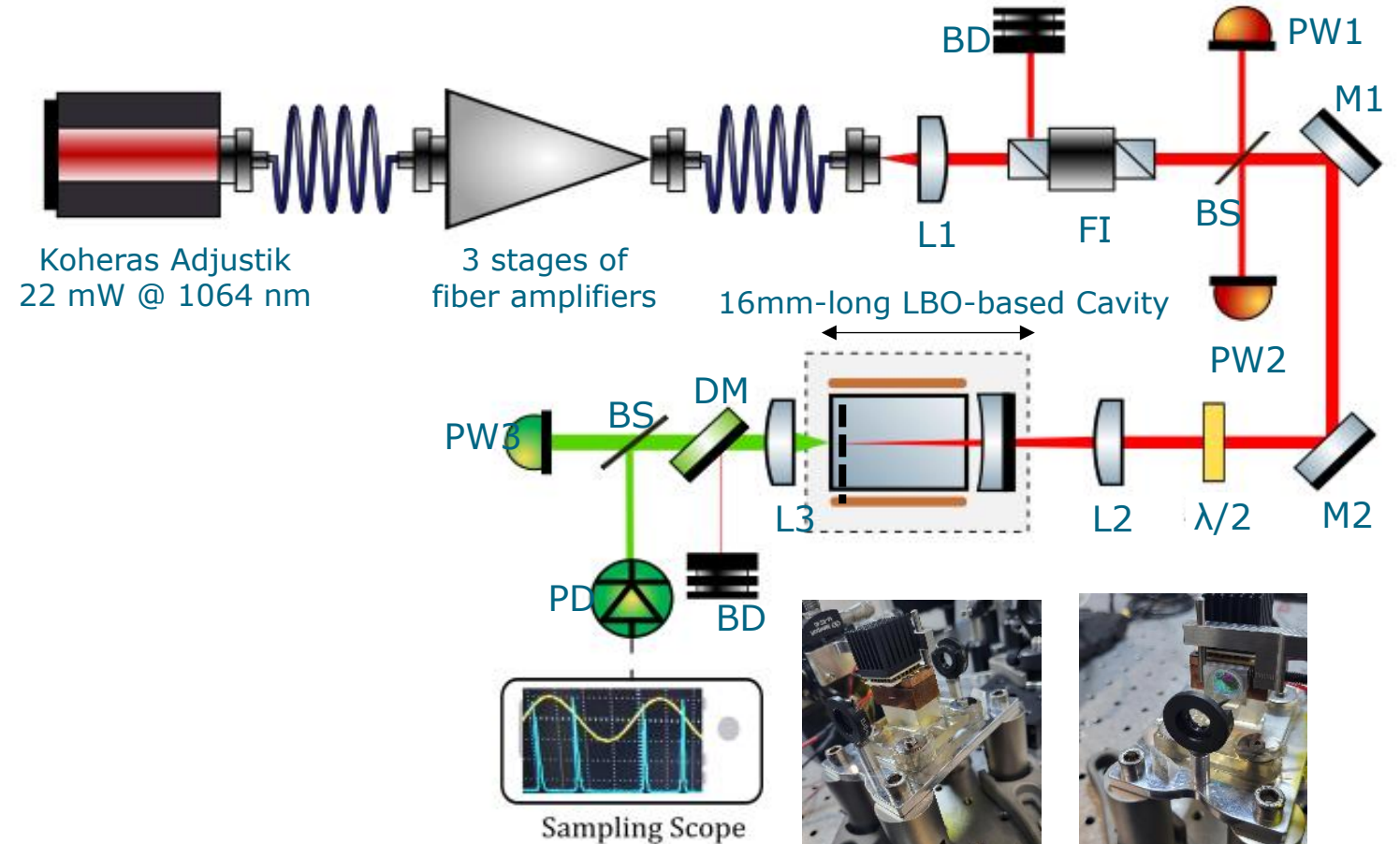
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Experimental setup : semi-monolithic LBO based resonant cavity “free – running cavity”

Standard configuration

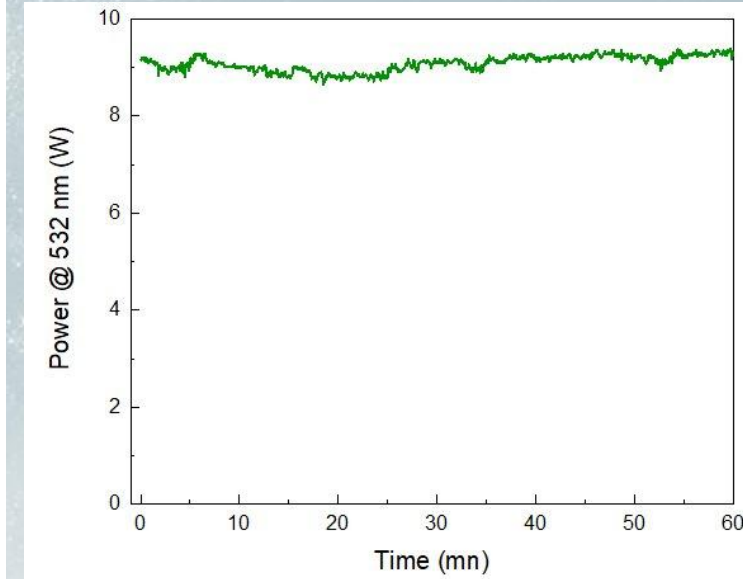
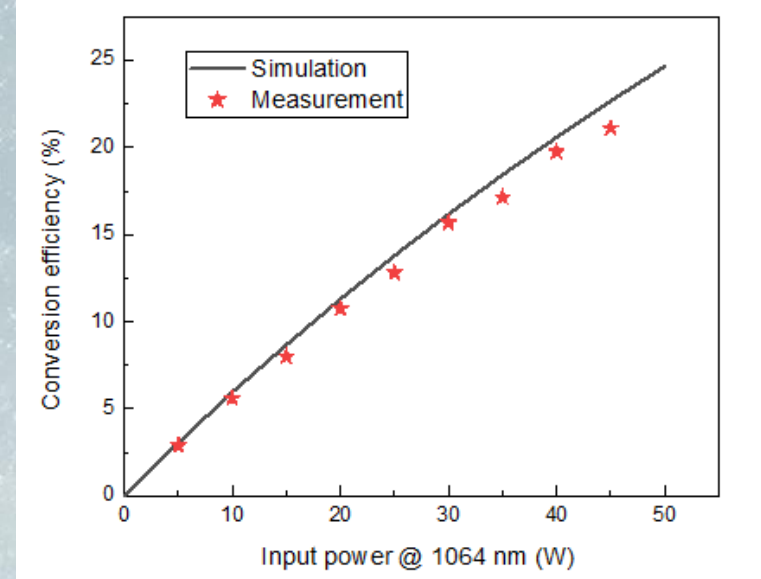
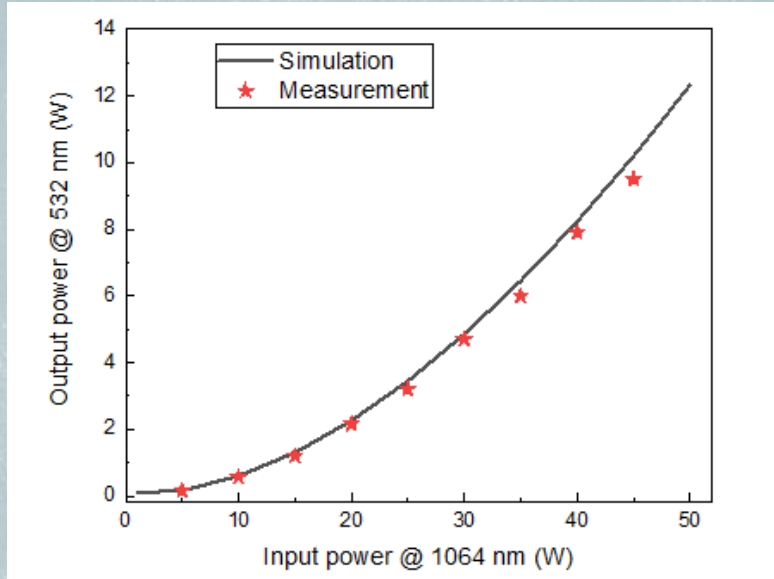


- Active Frequency stabilization with piezoelectric mounts
- Phase matching with crystal temperature oven



→ Passive architecture with only thermal regulation of the LBO crystal

Results



- 9.5 W @ 532 nm for 45 W @ 1064nm,
- > 20 % conversion efficiency , could be increase up to 35 % with 100W @ 1064nm ,
- RMS stability < 1.8% .

Conclusion

- ALPhNAOV is deeply involved in Photonics Defense applications.
- R&D roadmap for laser development is high average power fiber laser in IR and robust frequency conversion module for visible light.
- As we are a RTO, we are looking for opportunities to collaborate on European projects.



Thank you !!!

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Centre Technologique Optique et Lasers



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