Laser with tunable pulse repetition rate and high peak energy for photonic computing

Krzysztof Tyszka, Barbara Piętka

Polariton

UNIWERSYTET WARSZAWSKI

INICJATYWA DOSKONAŁOŚCI UCZELNIA BADAWCZA

I.4.2. Fund for the Renovation and Development of Research Infrastructure

WYDZIAŁ FIZYKI UNIWERSYTET WARSZAWSKI

Requirements

- Pulsed laser
- Tunable pulse rate
- High peak energy (1 uJ)
- Tunable in VIS, NIR
- Narrow spectral width
- Pulse On-Demand
- Bursting
- Fully automated tuning

Fluence .technology

Yt Fiber Laser + OPA

709 752,- PLN

IDUB 496 826,- PLN

FUW 212 925,- PLN

Discount 87 720,- PLN

2nd offer 245 784,- EUR

Laser setup

PUMP
Pulse : λ = 1030 nm, 50 uJ (max), 20 Mhz (max)
250 fs – 8 ps
Pulse picker (const. E) 0. – 1 Mhz

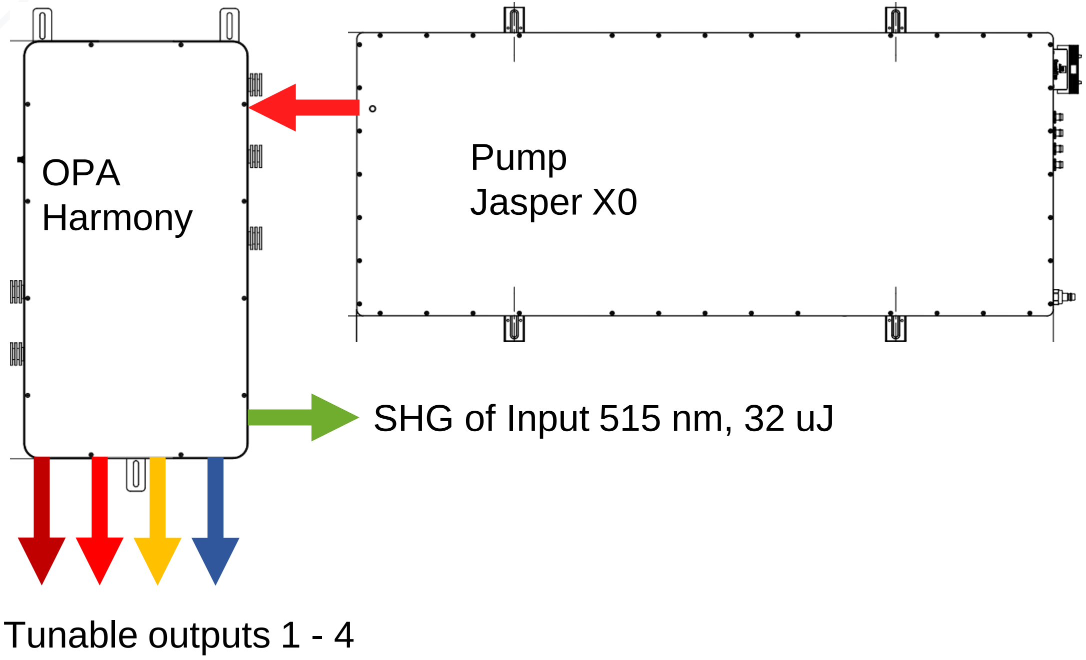
Monolithic all-fiber, fast warm-up time, long-term stability and hands-free operation, high BP stability

OPA

Automated tuning (software)

4 separate outputs:

1. SSH 315 - 515 nm
2. ISH 515 – 630 nm
3. Signal 630-1030 nm
4. Idler 1030-2600 nm



OPA Pulses

Pulse widths:

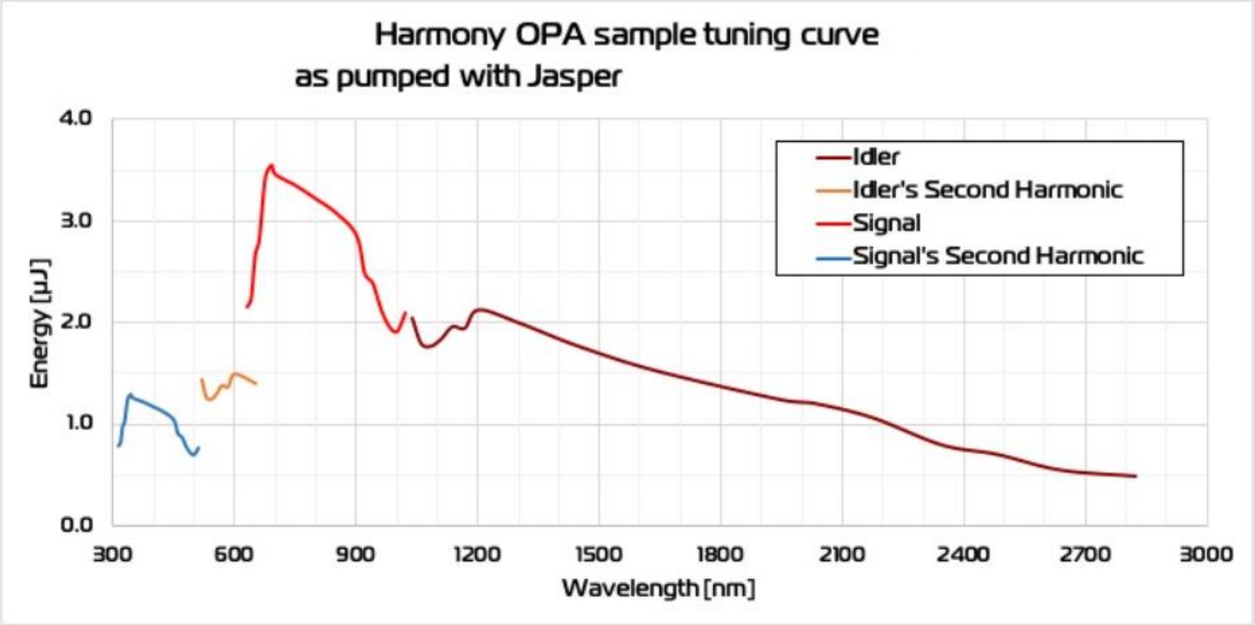
OPA IN 1030 nm, < 9 nm

OPA OUT 2 ps, < 0.7 nm

SHG 515 nm, < 0.28 nm

Automated tuning (software):

- Pulse picking: 0. – 200 kHz
- Pulse on demand
- Bursting



Laboratory setup

"Warm" LAB 3.56

Excitation
- **Fluence Laser**
- Tunable ns Laser
- SLM
- While Light Source

Sample
- Open cavity setup
- Microscope

Detection
- Spectrometer
- Thorlabs camera

Optical Fiber

"Cold" LAB 3.55

Excitation
- **Fluence laser**
- Pico-second 700-900 nm
- CW tunable 700-900 nm
- High power SLM
- White Light Source

Sample
- Continuous Flow Cryostat
- Confocal Microscope (4k, 9T)

Detection
- High Res. Andor Camera
- Spectrometer
- TCSPC (resolution 19 ps)

In both labs:
Polarization control, optical elements, mounts, optomechanical devices (e.g. rotators.)

Open access

- Google Sheets LAB schedule (staff)
- First-timers:
  - email request
  - qualified staff supervision
  - FUW, UW priority
- Outside projects in collaboration

(Low-power) strong optical nonlinearity

Problems

- Photons do not interact
- Lack of appropriate materials (non-linear medium)
- Usually high instantaneous power needed

Applications*

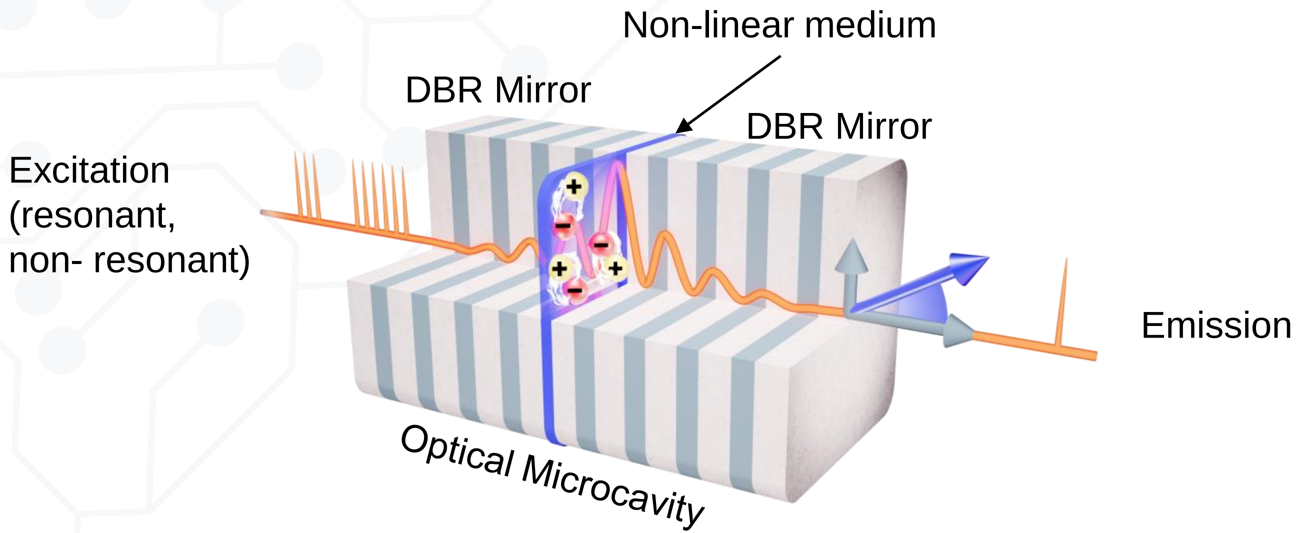
- Optical Analog computing
- Computing accelerators (for classical systems)
- AI, Machine learning accelerators

Photonics Prospects

- GHz regimes
- Low cross-talk
- Wavelength multiplexing
- Low power dissipation
- Photonics integrated circuits

*Solli, D.R. and Jalali, B. (2015) ‘Analog optical computing’, *Nature Photonics*, 9(11), pp. 704–706.
Wu, J. *et al.* (2022) ‘Analog Optical Computing for Artificial Intelligence’, *Engineering*, 10, pp. 133–145.
Stroev, N. and Berloff, N.G. (2023) ‘Renaissance of Analogue Optical Computing’. arXiv.2301.11760.

Experiment scheme



Optical nonlinearities

01. Thresholding

02. Bistability

03. Phase shifting

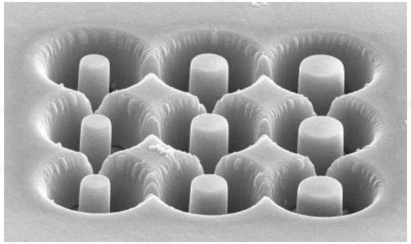
04. Wavelength shifting

05 ... other

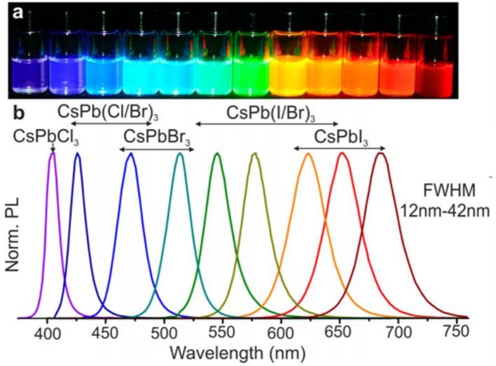
Materials

Wide range of novel photonic materials promising for non-linear response synthesized at WF, WCh, and CENT

CdTe, GaAs semiconductors

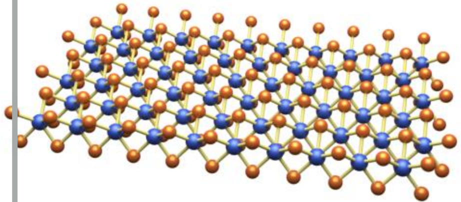


Perovskites



Bioinspired proteins mCherry, TdTomato

Transition metal dichalcogenides MoS_2, WSe_2, WS_2, $MoSe_2$



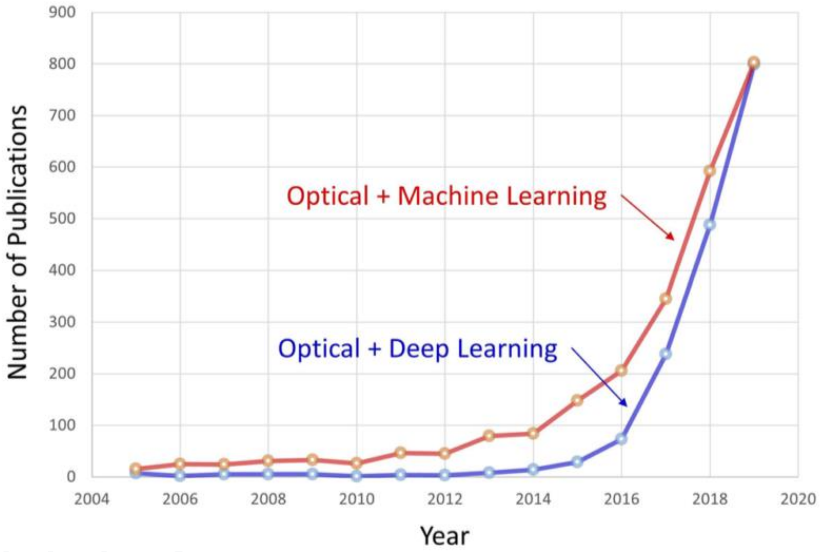
<u>Laser Requirements:</u>

1. Wavelength tunability
2. Pulse on demand, pulse picking, bursting (if low photostability of a material)
3. Sufficient peak energy (hard to obtain without an optimized solution)

... and others

MLPPP

Forefront of research.



AI boosts photonics and vice versa

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WWU MÜNSTER

Wolfram Pernice

- Very competitive field
- Broad perspectives for collaboration

PHYSICAL REVIEW APPLIED

Neural Networks Based on Ultrafast Time-Delayed Effects in Exciton Polaritons

R. Mirek, A. Opala, M. Furman, M. Król, K. Tyszka, B. Seredyński, W. Pacuski, J. Suffczyński, J. Szczytko, M. Matuszewski, and B. Piętka
Phys. Rev. Applied **17**, 054037 – Published 23 May 2022

Energy-Efficient Neural Network Inference with Microcavity Exciton Polaritons

M. Matuszewski, A. Opala, R. Mirek, M. Furman, M. Król, K. Tyszka, T.C.H. Liew, D. Ballarini, D. Sanvitto, J. Szczytko, and B. Piętka
Phys. Rev. Applied **16**, 024045 – Published 25 August 2021

NANO LETTERS

Neuromorphic Binarized Polariton Networks

Rafał Mirek, Andrzej Opala, Paolo Comaron, Magdalena Furman, Mateusz Król, Krzysztof Tyszka, Bartłomiej Seredyński, Dario Ballarini, Daniele Sanvitto, Timothy C. H. Liew, Wojciech Pacuski, Jan Suffczyński, Jacek Szczytko, Michał Matuszewski*, and Barbara Piętka*

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Leaky Integrate-and-Fire Mechanism in Exciton–Polariton Condensates for Photonic Spiking Neurons

Krzysztof Tyszka, Magdalena Furman, Rafał Mirek, Mateusz Król, Andrzej Opala, Bartłomiej Seredyński, Jan Suffczyński, Wojciech Pacuski, Michał Matuszewski, Jacek Szczytko, Barbara Piętka

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Thank you for your attention