TALENTS Photonique Nouvelle-Aquitaine

BOOK OF ABSTRACTS

2nd Photonics TALENT International Summer School

Remarkable Nonlinear Optical Response of non-van der Waals 2D Hematene and Magnetene Nanoplatelets Exfoliated from Mineral Ores Using a Green Synthesis Method for Ultrafast Photonic Applications

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Abstract

The two-dimensional (2D) analogs of hematite and magnetite, called hematene and magnetene, constitute the two archetype 2D iron-ore non-van der Waals materials. These nanostructures display exceptional magnetic and photo/electro-catalytic properties which are superior to those of their bulk counterparts due to quantum confinement and surface effects. In addition, because of their interesting optoelectronic features, it is speculated that hematene and magnetene could be used for innovative photonic and optoelectronic devices. However, such studies are still in their early stages, as investigations pertaining to the ultrafast nonlinear optical (NLO) properties of non-van der Waals 2D materials are rather scarce. In this context, the present work constitutes the first systematic investigation, to the best of our knowledge, of the ultrafast NLO response (NLO absorption and refraction) and its temporal evolution in hematene and magnetene 2D nanostructures prepared via a green synthesis method and dispersed in water. More specifically, for the assessment of their ultrafast NLO response and its dynamics, Z-scan and pump-probe optical Kerr effect (OKE) measurements were performed using 50 fs, 400 nm laser pulses. The results of the present work strongly suggest that hematene and magnetene can have applications in a wide range of photonic and optoelectronic applications.

Laser-assisted drug delivery to the inner ear

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Abstract

According to the World Health Organization, 466 million people worldwide suffer from hearing impairment, and by 2050, more than 700 million individuals (1 in 10) will be affected[1]. Promising therapies are currently being developed[2]; however, these treatments face challenges in crossing multiple and fragile tissue barriers to reach the inner ear[3]. Transtympanic injections, already used in clinical practice, rely on intracochlear drug diffusion through the round window membrane (RWM) but are limited by agent leakage through the Eustachian tube and uncontrolled diffusion. Laser-assisted bioprinting (LAB)[4,5] offers a promising solution for the precise and reproducible delivery of therapeutic agents to the cochlea, with micrometric resolution and a contact-free approach[6].

The objective of this study is to adapt LAB for laser-assisted drug delivery (LADD) to the cochlea using a transtympanic approach (Fig. 1a). To achieve this, a device was developed for otoendoscopic surgery and drug delivery on the RWM, using a Cobolt Tor™ XE laser (1064 nm, 1 – 3 ns) and a multimode fiber (105/125 µm, NA 0.22) for laser transport to the printing site. To ensure repeatable and circular droplet formation with optimal ink transfer, a multi-parametric analysis was conducted to determine the ideal ink composition, pulse energy, spot diameter, and distance between donor and receiving substrate. Additionally, laser-assisted texturing strategies were tested to locally and reversibly disrupt cellular junctions of the RWM, thereby enhancing drug diffusion into the cochlea. All experiments were conducted *in vitro* (inert material, 2D cell culture) and *ex vivo* (dissected mice cochleae).

Preliminary results show that 12.5% (w/w) poloxamer hydrogel[7] in PBS (10mM), with a pulse energy of 35µJ, a spot diameter of 250µm, and distance between donor and receiving substrate of up to 2mm enable precise deposition of therapeutic ink onto the RWM of dissected mice cochleae (Fig. 1b, 1c).

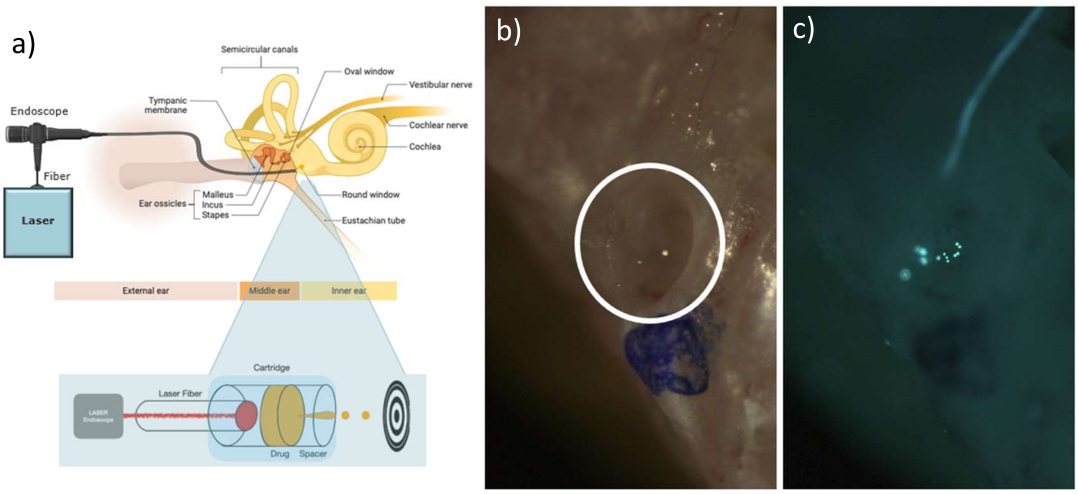

Figure 1 – a) Schematic representation of LADD to the inner ear. b) Visualisation of the mouse round window membrane and c) of the printed volume on the RWM of mice dissected cochlea using fluorescent microscopic beams. White circle diameter corresponds to 500µm.

These experiments will contribute to the design of a single-use cartridge for contact-free transtympanic delivery (Fig. 1a), and the development of an RWM permeability-enhancing strategy to maximize drug diffusion. As a result, this study will pave the way for *in vivo* experiments on laser-assisted gene therapy delivery in a mouse model of congenital sensorineural hearing loss.

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Femtosecond Laser-Textured Molds for High-Precision PDMS Surface Engineering

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Abstract

Polydimethylsiloxane (PDMS) is widely used in microfluidics, biomedical applications, and electronics due to its biocompatibility, transparency, and chemical resistance [1]. Typically, structuring its surface requires molds, with soft lithography being one of the most common approaches. However, this technique relies on molds that demand lengthy and resource-intensive fabrication processes, making it less efficient for complex microstructures [2]. This study explores the realization of femtosecond laser-textured aluminum alloy (AA2024) molds as a high-precision, cost-effective alternative for fabricating PDMS surfaces with controlled hydrophobicity. The sheets were laser-textured using a TruMicro Femto Laser system (Trumpf GmbH, Ditzingen, Germany) to create grid structures with controlled hatch distances and depths. Additionally, Laser-Induced Periodic Surface Structures (LIPSS) were generated to assess nanoscale replication capabilities. PDMS was then cast onto the molds and cured under standard conditions [3]. The quality of resulting surfaces was analyzed using both an optical microscopy and a profilometer. While, the wettability was evaluated by measuring the contact angle (CA) of different volumes droplets. This demonstrated the accurate replication of laser-fabricated microstructures from the aluminum mold onto the PDMS surface, leading to significant wettability changes. Furthermore, the replication process successfully transferred LIPSS onto PDMS with nanometer-scale accuracy, confirming the ability of the developed method to accurately reproduce micro- and nanostructures. In conclusion, the proposed fs-laser based method enables precise control over PDMS surface morphology and wettability, offering a promising approach for optimizing PDMS properties in biomedical devices, microfluidics, and surface engineering applications.

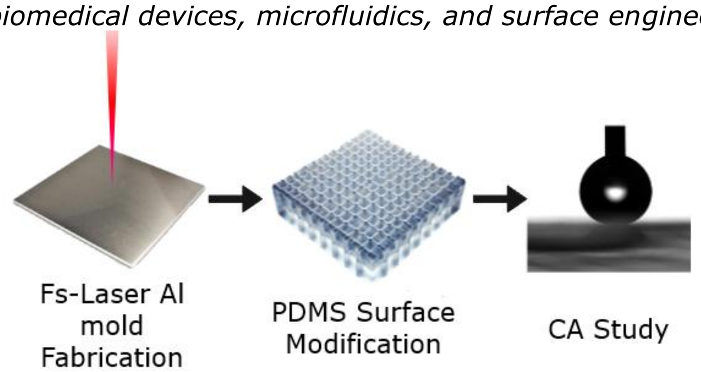

Figure 1: Graphical diagram of the process. (a) Femtosecond laser aluminium substrate texturing; (b) modified PDMS surface after the curing process [3]; (c) C.A. study and surface characterization.

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Frequency stability transfer over a wide spectral band using fibered Bragg grating cavities

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Transferring the stability characteristics of an optical frequency reference to another application wavelength is a key challenge in laser metrology. This involves transferring both frequency stability and spectral purity [1]. Many applications require these characteristics such as high-resolution spectroscopy, instrument synchronization, ultra-sensitive coherent detection for high-capacity telecommunications, or coherent manipulation of quantum states in atomic systems (atomic clocks, single-photon sources and qbits). For this purpose, frequency combs are commonly used in metrology laboratories.

In this study, we explore an alternative approach based on the transfer capabilities offered by fiber cavities, leading to simpler, more versatile, and more compact solutions. The transfer principle consists in locking the optical frequency of one cavity mode to the reference laser and using another mode of the same cavity to lock and thus stabilize the optical frequency of the target laser. This transfer solution is limited by the single-mode operation of the fiber. The spectral resolution for the target frequency is given by the cavity free spectral range (FSR), smaller than commercial combs repetition rate. Moreover, transfer of spectral purity is ensured by the ability to have fine and intense resonances at two distant wavelengths, that of the reference and that of the target.

We have already demonstrated the transfer of the stability from a fiber ring cavity at the 5.10^{-15} level [2]. It provides quasi-continuous transfer with a 1 MHz spectral resolution (200m long cavity), but the transfer is limited to 100 nm due to the input coupler. To overcome this limitation, we present in this communication another scheme relying on two nested Fabry-Perot cavities based on fiber Bragg gratings (FBGs) embedded in the same single-mode fiber, limiting the transfer by the cut-off frequency of the fiber. Another advantage of FBGs is their ability to achieve the same resonance characteristics at both wavelengths.

This approach is demonstrated for a transfer from a metrological reference laser operating at λ=1542 nm to a target laser at 1064 nm. For this purpose, each cavity consists of two FBGs photo-inscribed within a Corning HI1060FLEX fiber, which remains single-mode up to 980 nm. The gratings are separated by 150 meters, giving an FSR of 700 kHz (Fig. 1a)) [3].

Frequency stability transfer based on a fiber cavity is limited in the short term by fiber vibrations and in the long term by fiber temperature fluctuations. We have developed a packaging solution to minimize thermal, acoustic, and vibrational disturbances (Fig. 1b). The optical length of the cavity at 1542 nm is actively controlled from the frequency error signal by locking one of its modes to the reference using a PZT and several Peltier modules. The target laser is then locked onto one mode of the 1064 nm cavity. Preliminary results show that this packaging reduces fiber temperature variations by a factor of 50 (Fig. 1c).

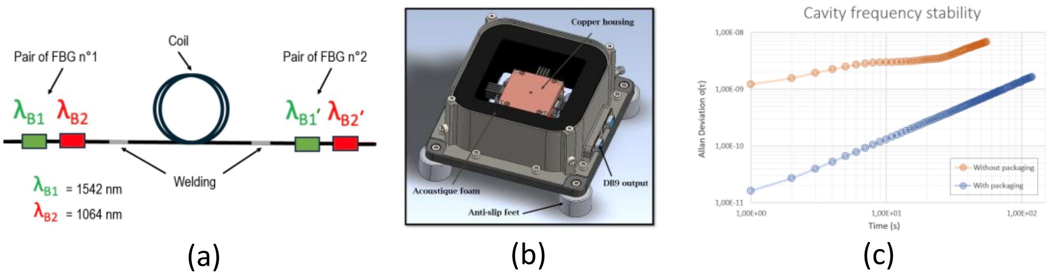

Fig. 1 Sketch of the two wavelengths resonant FBGs cavity (a). Packaged cavity (b). Cavity stability improvement using passive packaging (c).

Acknowledgments: This work is supported by the LABEX FIRST-TF Excellence Cluster (ANR-10-LABX-48-01).

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New Approaches for High Power Ultrashort Lasers

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Abstract

Recent advances in ultrashort lasers have steered into the development of ultrashort lasers with moderate peak power and high average power. It is only at the kilowatt power regime that some applications, such as high flux charged particle beams or extreme ultraviolet (EUV) sources, become comparable to radiofrequency technology and industrially applicable.
Additionally, some efforts have been directed towards the path of longer wavelength lasers (at mid-infrared > 2μm) as opposed to current near-one micron lasers (1.03 μm for Yb:YAG, 0.8 μm for Ti:Sa). This path introduces a scaling law which is interesting for high power plasma physics experiments; the strength of the interaction is proportional to the wavelength squared (λ^2) so in theory one could get the same laser-matter interaction effect with many times less energy, which automatically decreases potential thermal loads [1]. It would also offer some advantages in high harmonic generation (HHG) such as extended cutoff energies (given the dependence of the ponderomotive energy with λ^2).

The result of this work would be to generate a laser system able to output short pulses on the order of femtoseconds at a high repetition rate. The proposed architecture for the laser is pictured on Fig. 1. It would employ a hybrid scheme, based on Chirped Pulse Amplification (CPA) and Optical Parametric Chirped Pulse Amplification (OPCPA), so that each of these techniques can be used in optimal conditions. Instead of using a Tm or Ho oscillator, the plan is to use a Yb based oscillator that pumps an Optical Parametric Oscillator (OPO) to generate ultrashort 2 μm pulses plus become the seed for a set of Yb:YAG regenerative amplifiers that would pump the Optical Parametric Amplifier (OPA) stages. Recent advances in Tm-ion based lasers [2] make them attractive for CPA, which is the best technique to be used for the latest set of amplifiers to extract the highest energy from solid-state media. It is also important to note that all the setup can be fully pumped with laser diodes, increasing the overall efficiency of the laser chain.

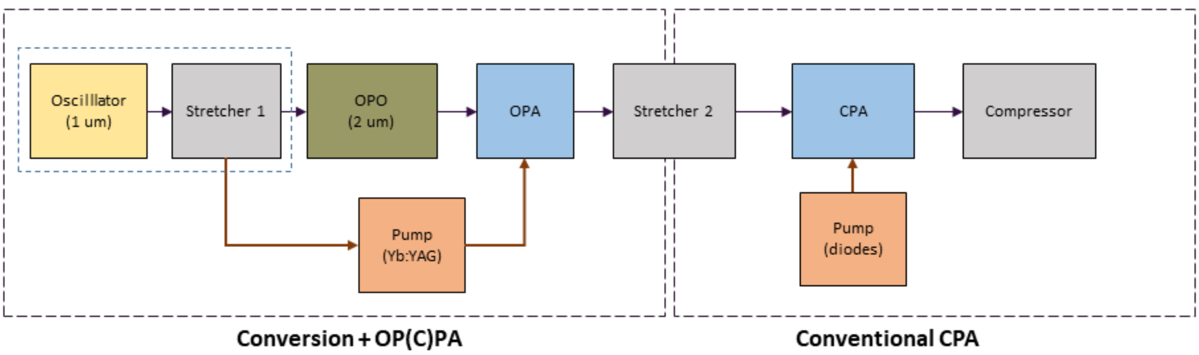

Figure 1: Proposed architecture for a high average power ultrashort pulse laser at 2 μm wavelength.

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Laser-Induced Birefringence Analysis in Transparent Dielectric Materials Using an Automated Circular Polarimeter

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Abstract

Ultrafast laser welding is emerging as a promising alternative to conventional optical adhesive bonding used in industry. Especially, transparent laser welding of dielectric materials is a hot topic. However, laser-induced residual stresses in optical materials can significantly affect their mechanical or optical performances, particularly in high-precision applications such as laser systems. To quantify these stresses, we implemented an automated monochromatic circular polarimeter to measure stress-induced birefringence [1-3]. This photoelastic technique determines the optical retardation in bonded samples using the Patterson and Wang 6-step method [2], enabling the evaluation of the internal stresses. Providing a non-destructive and precise approach to stress analysis, this method offers valuable insights into the mechanical integrity of optical components, contributing to a deeper understanding of their behavior across various applications.

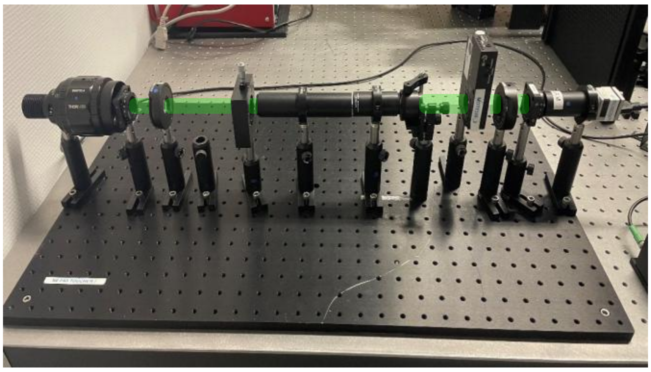

Fig. 1: Automated monochromatic circular polarimeter set-up

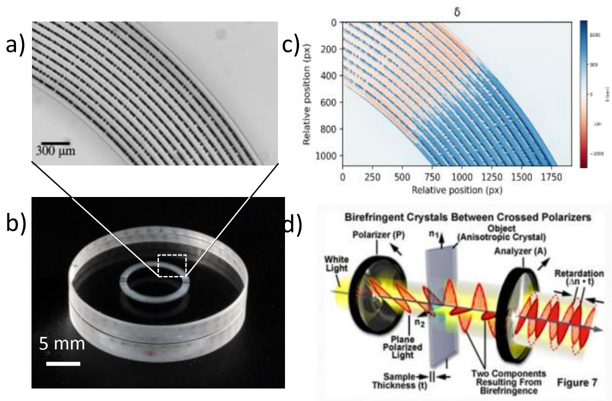

Fig. 2: (a) Micrography of the sample to analyze with Patterson and Wang 6-step method. (b) Picture of the full sample, 3 mm-thick fused silica windows welded with ultrafast laser, the welding pattern is a donut. (c) Optical retardation (nm) of the bonded sample**.**
(d) Scheme of birefringent crystal placed between two crossed polarizers [4].

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Ultrafast Laser Bessel Beam Interaction with Fused Silica in Single Pulse, MHz-Burst, and GHz-Burst

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Abstract

In this study, we show the use of spatial Bessel-beam shaping to produce high-aspect-ratio micro-channels in different regimes - single pulse, MHz-burst or GHz-burst. We investigated the influence of pulse energy and temporal shaping on the elongated bulk modification shape and the inner wall quality. Then, we used selective chemical etching to produce micro-channels. The results in terms of etching rate and micro-channel morphology are discussed regarding laser parameters and compared to previous results published in the scientific literature [1,2]. Our findings constitute a significant contribution to advancing micro drilling and sub-surface structuring of transparent dielectrics, especially for applications requiring high-precision material removal. Moreover, we demonstrate single step and chemical-free micro-channel drilling using a single GHz-burst, which is extremely interesting for applications like Through Glass Via (TGV) fabrication in thick glass.

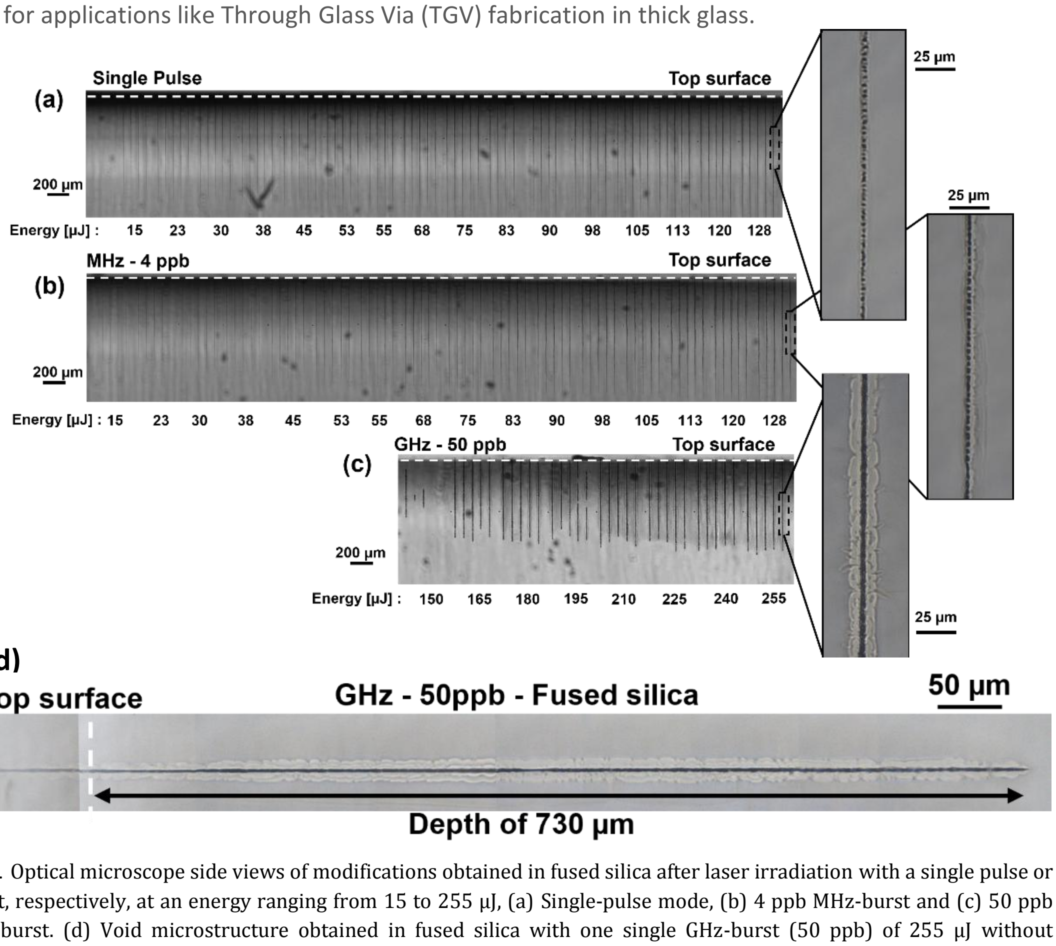

Fig. 1 Optical microscope side views of modifications obtained in fused silica after laser irradiation with a single pulse or burst, respectively, at an energy ranging from 15 to 255 µJ, (a) Single-pulse mode, (b) 4 ppb MHz-burst and (c) 50 ppb GHz-burst. (d) Void microstructure obtained in fused silica with one single GHz-burst (50 ppb) of 255 µJ without chemical etching. Top surface is on the left. The pitch between two modifications of same energy is 50 µm. The white line at the top of each microscope image represents the top surface. The inserts on the right are a zoom of the highest energy modification delimited by a rectangle of black lines.

Example References

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Quantum machine learning models for cancer detection

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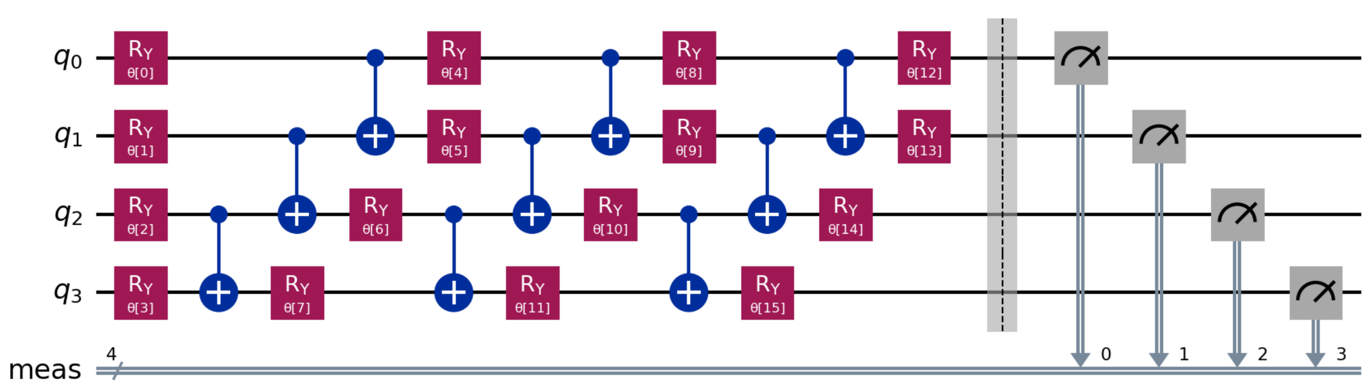
Abstract

Cancer is the second biggest cause of human deaths. Early diagnosis is a key element of full recovery or long overall survival. Liquid biopsies are excellent alternatives to traditional biopsies and imaging for cancer detection as they are minimally invasive and their cost is decreasing. In recent years, there has been a growing interest in machine learning techniques and models regarding liquid biopsy analysis. Both fields of artificial intelligence and quantum computation are growing rapidly in recent years. Intersection between machine learning and quantum computation promises great possibilities. It this work I am presenting the Support Vector Machine method in its classical version and in the version enriched by quantum computation. I am comparing both approaches and presenting applications of Quantum Support Vector Machine in biomedical research.

Ansatz

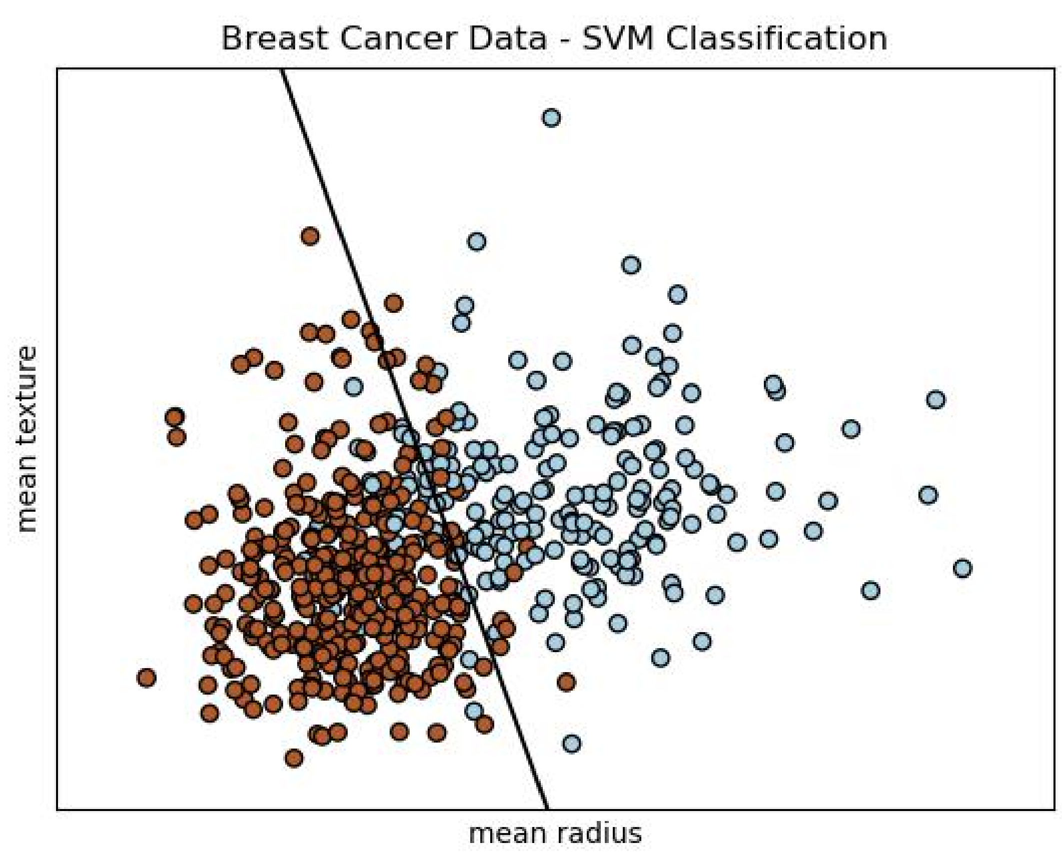


Support Vector Machines SVM

Support Vector machines are powerful supervised learning models used for regression and classification tasks. They working by finding optimal hyperplane that best separates dat points into different classes or predicts continuous values.

- **Hyperplane** is a decision boundary that divides data into classes .
- **Support vectors** are data point closest to hyperplane .
- **Kernel** is the function that maps data to higher dimensional space.

SVM classification diagram



Support Vector Classification SVC

SVC solves the following primal problem:

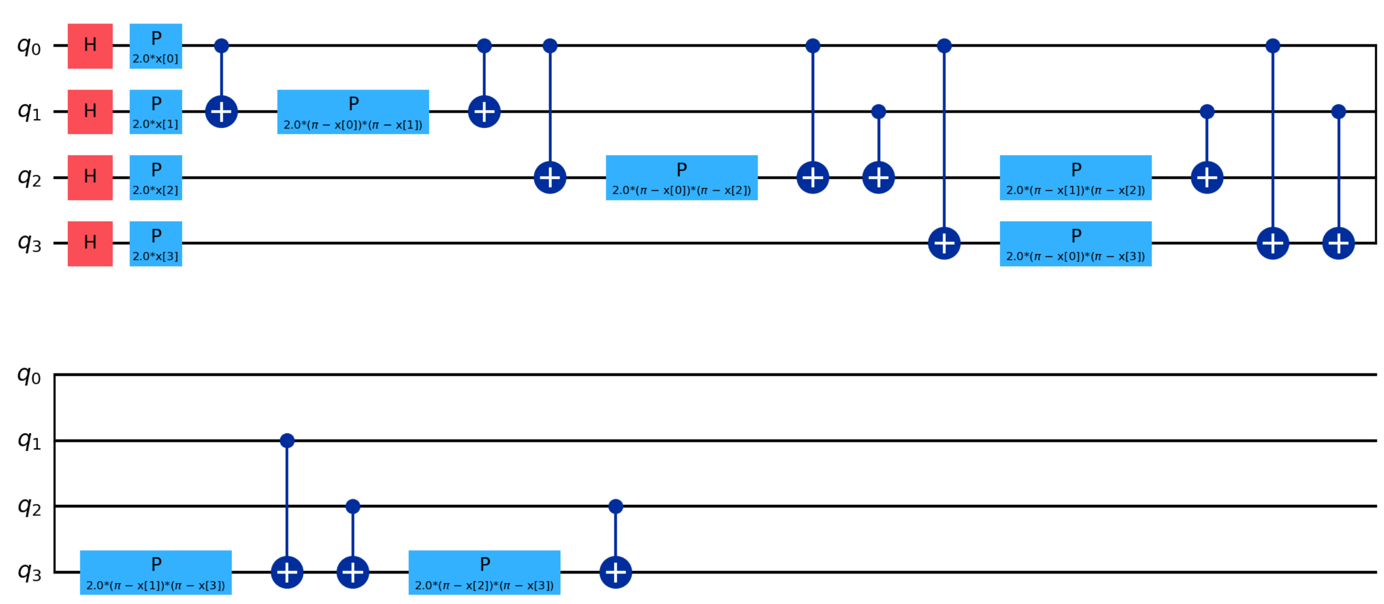
$$\min_{w,b,\zeta} \frac{1}{2} w^T w + C \sum_{i=1}^{n} \zeta_i \quad (1)$$

subject to

$$y_i(w^T \phi(x_i) + b) \geq 1 - \zeta_i \quad (2)$$

$$\zeta_i \geq 0, i = 1, ..., n \quad (3)$$

Feature map for QASM simulator

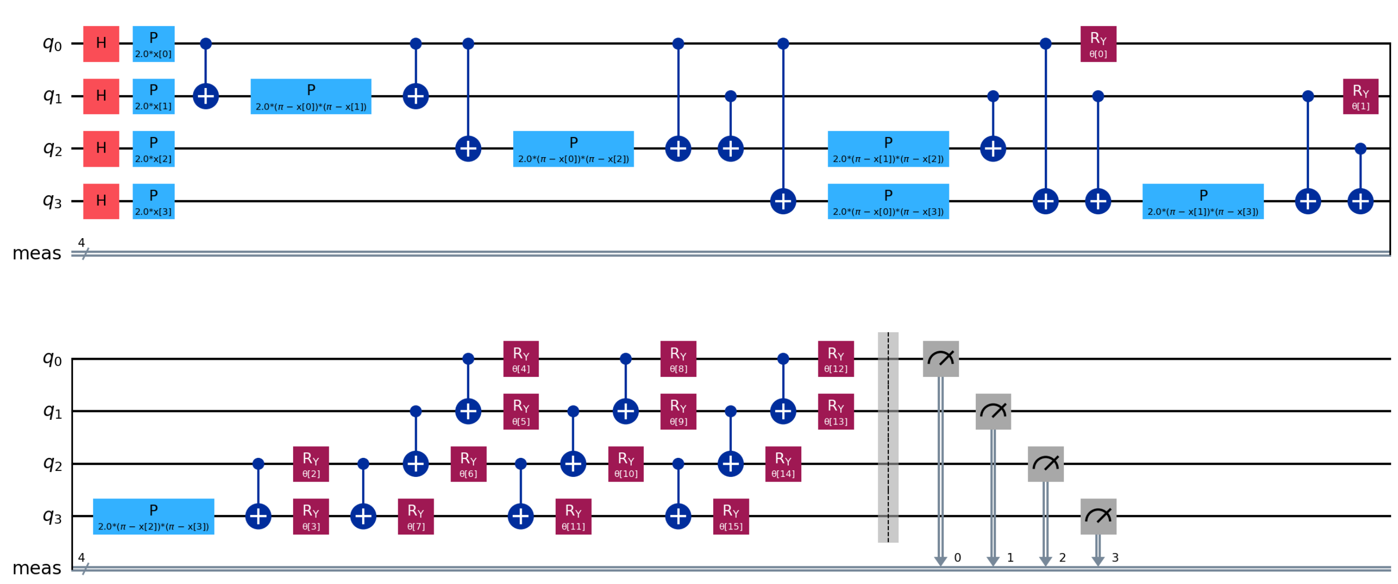


Variational Quantum Classifier

Variation Quantum Classifiers are a kind of hybrid quantum machine learning models.

- VQC first encodes the data into a quantum state. For this purpose, a feature map is used. It is a quantum circuit that takes classical data as an input and gives quantum data as an output.
- Secondly, quantum data is processing by variational quantum circuit and can be parametrized by set of parameters.
- These parameters are optimized by machine learning algorithm to minimize a loss function.

Complete circuit, including the feature map



Resultes

Method	Accuracy
SVM	0.96
VQC	0.84

Table 1. Accuracy.

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OPTIMIZATION OF LASER PARAMETERS FOR THE TEXTURING OF CERAMIC THERMAL BARRIER COATINGS FOR NON-WETTABILITY AGAINST CMAS

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Abstract

The turbojet engine's corrosion induced by sand and volcanic ashes (CMAS) is a real scourge for aeronautic industry [1]. If different solutions have been studied, including modifying the chemical composition, none have been completely effective [2]. Our research project therefore aims to find a complementary or alternative solution to CMAS attacks, based on studying the physical aspects behind CMAS wettability on zirconia-based materials (here 8%mol. yttria partially-stabilized zirconia, "YSZ"). We will be particularly interested in the impacts of YSZ crystal orientation, porosity and roughness distributions on surface energy variations and thereafter on the wettability of a specific CAS mixture (23.5wt%CaO-15wt%Al_2O_3-61.5wt%SiO_2). To achieve this, two technical paths are being jointly investigated: laser glazing and laser texturing of YSZ.

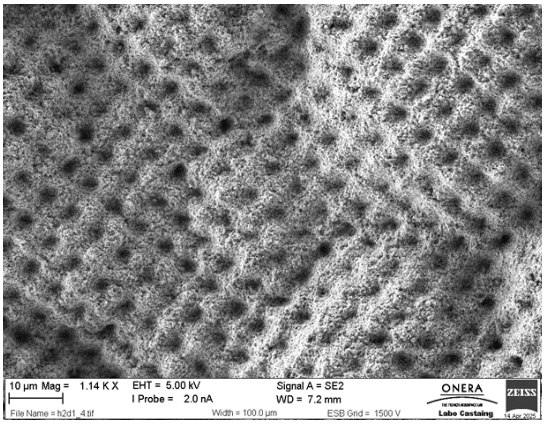

Figure 1 – SEM image of Laser Texturing by Direct Laser Interference Patterning (DLIP) on suspension plasma-sprayed ("SPS") YSZ.

The part presented here will focus on the work done with the laser texturing method called Direct Laser Interference Patterning (DLIP), which is a technology developed at Alphanov [3].
Indeed, a key step have been to understand the interaction between the laser and our samples, both sintered YSZ coupons and suspension plasma-sprayed ("SPS") YSZ coating.
Through the characterization of the different results obtained by varying the laser parameters, such as roughness or regularity of texturing, it will help to find the optimal parameters. Finally, the influence of texturing on the desired non-wetting with CMAS property will be observed thanks to CAS wetting experiments in temperature, through novel laser-rig tests carried out at ONERA facility.

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Hybdrid PCMA-FCPA Yb-fiber amplifier delivering 76 MHz repetition rate and 72 W average power femtosecond pulses

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Abstract

Over the last several decades, significant advancements have been made in the development of high average power (>50W) and high repetition rate (tens of MHz) ultrashort laser systems, which are essential for applications like nonlinear microscopy, holography, and spectroscopy [1]. Ytterbium-doped, large mode area photonic crystal fiber amplifiers are often seen as ideal candidates for laser amplification, due to their outstanding optical, thermal, and mechanical properties [2,3]. However, direct laser pulse amplification in fiber-based systems can lead to laser induced damage and complex pulse distortions due to interaction between material dispersion, gain and nonlinear effects.

In this study, we present a robust femtosecond PCMA-FCPA Yb-fiber amplifier, that offers highly stable performance with excellent spatial and temporal characteristics, all within a relatively compact design. The seed pulses form an Yb:KGW oscillator were stretched in a transmission diffraction grating-based stretcher, amplified in an Yb-doped polarization-maintaining rod-type LMA PCF pumped by a CW laser diode and compressed in a transmission diffraction grating-based compressor. By optimizing the initial stretched pulse duration (Fig. 1), we achieved over 82 W of average pulse power directly after amplification, with a slope efficiency of 54%. After compression losses, the system outputted 72 W of average power, with nearly transform limited pulse duration of 114 fs and pulse energy roughly equal to 1 μJ. These pulses were then used to generate >30 W (56% conversion efficiency) of second-harmonic signal and a supercontinuum seed from a bulk KGW crystal (Fig. 1), which will be used for development of high repetition rate optical parametric amplifier.

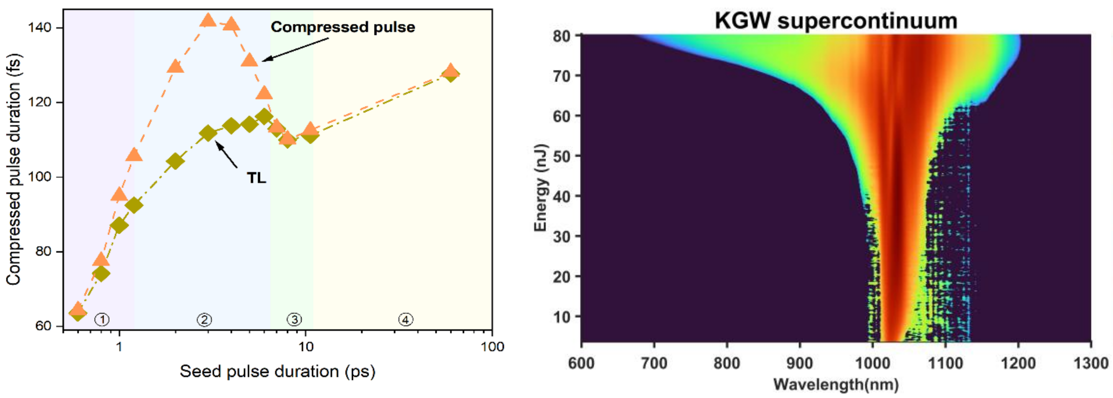

Fig. 1 Left – compressed amplified pulse duration dependency on initial pre-chirp value. Right – supercontinuum spectrum generated from KGW crystal.

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35 W Core-Pumped Holmium Fiber Laser

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Abstract

Holmium fiber lasers offer broad emission around 2.1 µm, which coincides with an existing atmospheric transmission window, enables applications such as LIDAR, remote sensing and free-space optical communication [1]. Some challenges arise due to using silica as fiber material, mainly the increasing intrinsic absorption beyond 2 µm, OH^- absorption [2] and the limited solubility of rare-earth ions. These problem can be addressed by high purity fibers and by introducing sufficiently high alumina co-doping, as there seems to be a direct link between the molar ratio of Al/Ho and slope efficiency [3].

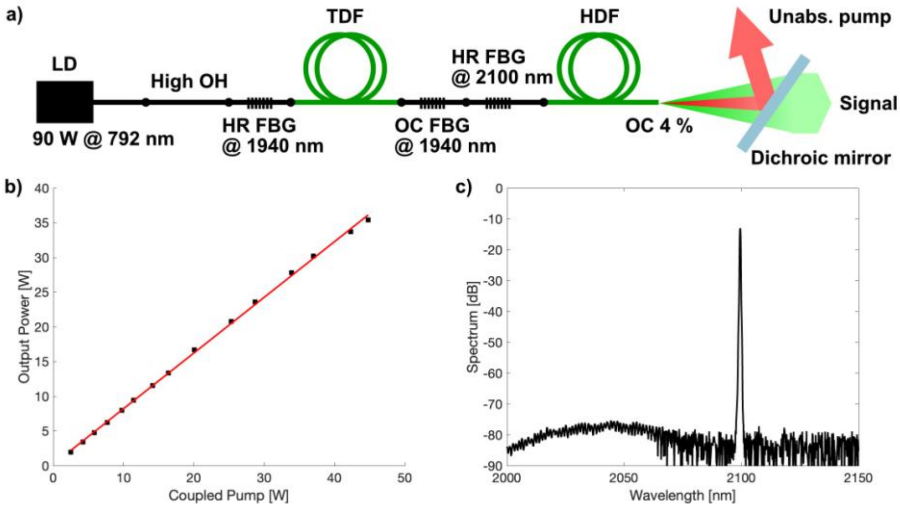

Fig. 1 a) Experimental setup. b) Measured output power and linear fit with 80 cm fiber. c) Output spectra at full power.

The experimental setup is shown in Fig. 1a. We obtained a maximum output power of 35.4 W at 2.1 µm for a coupled pump power of 44.8 W as shown in Fig. 1b. This output power is, to our knowledge, the highest obtained from a resonantly core pumped holmium fiber laser. The optimal fiber length was 80 cm for optimal optical efficiency of 79 %, a length of 60 cm was optimal for efficiency relative to absorbed pump power of 81 %. The laser shows good signal to noise ratio as shown in Fig. 1c.

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Tunable low-noise single-frequency fiber laser source from 1830 to 1880 nm delivering 50 W for quantum applications

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Abstract

Thulium-doped fiber amplifiers (TDFAs) emit broadly across 1600–2100 nm. Most designs target 1900–2000 nm using high-power 793 nm cladding-pumped lasers, leaving the 1800–1900 nm range underexplored despite its relevance for quantum computing (e.g., high-power 840 nm sources via nonlinear conversion with 1550 nm lasers). Meleshkevich et al. (2005) achieved 10 W at 1780 nm in an all-fiber system using 1567 nm core-pumping. This configuration is generally limited in power scaling due to the challenges in developing high-power, single-mode laser sources around 1570 nm. Despite this, Burns et al. (2019) remarkably achieved 47 W at 1726 nm with an 80 W, 1580 nm erbium-doped fiber laser [2] but used free-space injection and non-PM fibers, unsuitable for industrial use. We present a polarized, fully fiberized 1844 nm laser amplifier delivering 47 W, leveraging double-clad fibers pumped by 793 nm diodes (Fig. 1).

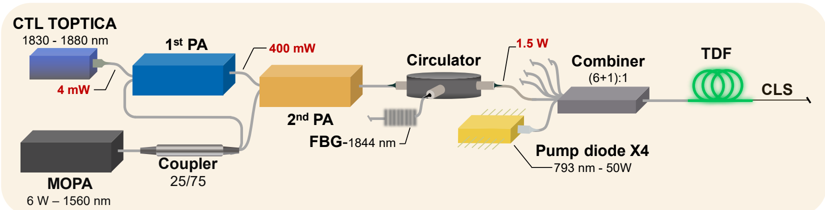

Fig. 1 Schematic of the three all-fiber amplification stages. SF; MOPA – Master Oscillator Power Amplifier; FBG – Fiber Bragg Grating; TDF – Thulium-Doped Fiber; CLS – Cladding Light Stripper.

The system is a three-stage MOPA amplifier with a low-noise, single-frequency, tunable ECDL (1830–1880 nm) (CTL TOPTICA). The first two stages are core-pumped at 1560 nm by a low-noise MOPA delivering 6 W, split by a 25/75 coupler. A circulator and Fiber Bragg Grating (FBG) at 1844 nm filter the second preamplifier output, achieving 1.5 W with an OSNR >80 dB. The final stage is clad-pumped by four multimode diodes emitting 50 W at 793 nm. Results after the cladding mode stripper are shown in Fig. 2.

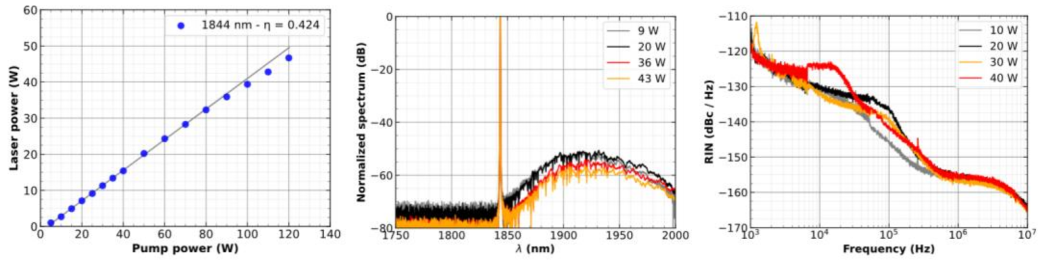

Fig. 2 Laser output characterization: (a) power, (b) spectra, and (c) RIN.

Fig. 2-(a) shows laser output power versus pump power. Below 80 W, the system achieves 42% efficiency; above this, pump wavelength shifts reduce efficiency. A maximum of 47 W is achieved, the highest reported for an all-fiber configuration in this range. Fig. 2-(b) shows an OSNR exceeding 50 dB, improving with power scaling. Fig. 2-(c) demonstrates stable RIN with power scaling, indicating no stimulated Brillouin scattering [3]. Future optimization will focus on reducing low-frequency intensity noise with optimized multimode pumps. We have demonstrated 900 hours of continuous operation at 30 W and over 200 hours at 47 W, showing system robustness. This is the first demonstration of a 50 W-class low-noise full-fiber system around 1844 nm. This system is key for generating new NIR wavelengths (840 nm) via SFG with 1550 nm lasers for demanding quantum applications.

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Ultrafast Laser Micromachining of Quartz-Based Microresonators: Towards Scalable and Sustainable Manufacturing

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Abstract

Microscale resonators are crucial in precision sensing and frequency control applications. However, the manufacturing of these devices is often constrained by costly and environmentally harmful etching techniques [1]. This study investigates the application of femtosecond laser processing as an environmentally friendly alternative to conventional techniques for the fabrication of quartz-based microresonators, particularly Quartz Tuning Forks (QTFs). The proposed approach employs a 515 nm femtosecond laser source coupled with a galvoscanner, enabling direct micromachining of quartz wafers with precise control over taper angle and edge roughness. The laser processing parameters, including pulse energy and scanning velocity, were systematically optimized to ensure high-quality cuts with minimal structural defects.

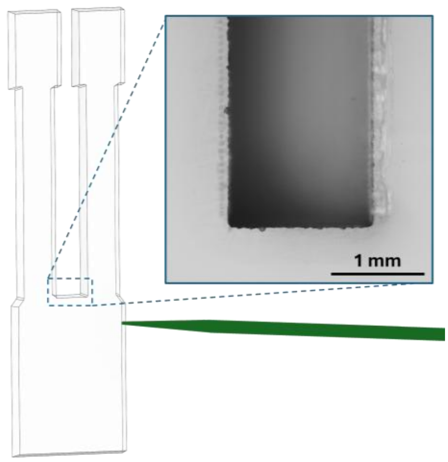

Figure 1. QTF design used for processing. The inset shows an optical microscope image of the facets at the support-prongs junction of the QTF.

Finite element analysis was used to simulate the strain field distribution on the QTF surface when excited at its fundamental flexural vibrational mode. An experimental setup was designed and assembled to excite the QTF in this mode and a laser vibrometer was used to measure the lateral displacement of a QTF prong. By reconstructing the resonance curve, the resonance frequency and the quality factor of the QTF were determined. The measured resonance frequencies of the laser-cut QTFs showed excellent agreement with theoretical predictions, with deviations of less than 0.2%. The quality factor was found to be highly dependent on the presence of microcracks in the junction area between the prongs.
In conclusion, this work demonstrated that femtosecond laser processing is a viable technique for manufacturing high-precision quartz resonators, offering significant advantages in terms of flexibility, scalability, and sustainability with respect to standard etching techniques.

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Thulium-doped fiber laser with segmented active fiber

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Abstract

Two-micron sources of radiation are in high demand for their widespread utilization in areas such as defence, industrial, or biomedical applications. Thulium-doped fiber lasers offer access to a wide emission spectral range in this region and moreover enable the so-called two-for-one cross-relaxation process leading up to the theoretical doubling of the overall quantum efficiency up to 2 [1]. Nowadays, one of the main challenges is thermal management, as the active fiber core can reach up to 300 °C during the laser operation, but power scaling is hindered by the much lower temperature limit of the polymer outer-coating around 80 °C [2].

One prospective method to significantly reduce thermal load density along the fiber is using a segmented active fiber or active fiber with a longitudinal gradient of Tm-doping concentration. These fibers would benefit from lower Tm concentration at the beginning of an active fiber where significant heat load can be expected due to high pump absorption, and high concentration towards the far end of the fiber, enabling an efficient 2-for-1 process [3].

Based on a theoretical model, the laser design with a longitudinally segmented active fiber was proposed and initial measurements and tests were done. The results indicate that, in comparison to uniformly doped fibers, the heat load can be spread more evenly within the whole fiber length. As this fiber was composed of several segments spliced together, the output laser characteristics are affected by the splices, which could be improved by using a single fiber with a concentration gradient. Even though it was possible to reach up to 30 W of output power at 1940 nm with launched slope efficiency exceeding 60 %. The laser performance is shown in Figure 1.

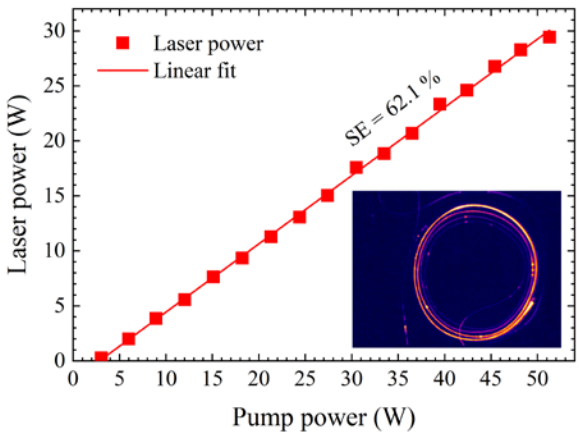

Figure 1. Performance of the segmented fiber laser and a thermal camera image.

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Novel hybrid fiber/bulk ultrafast CPA system at 2.05 µm

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Abstract

Our research focuses on developing a Chirped Pulse Amplification (CPA) system [1] that uniquely combines fiber and solid-state technologies, which represents a novel approach in the field. Our goal is to develop a high-energy and high-power, high-repetition-rate, picosecond-scale, 2.05 µm laser system capable of producing ~10 mJ of pulse energy at a 1 kHz pulse rate. The output of this system will be used as a pump source for an Optical Parametric Amplifier (OPA) system to generate pulses in the mid-Infrared (midIR) region.

Our starting source is a Soliton Self-Frequency Shift (SSFS) laser that emits pulses at 2.05 µm with a pulse repetition rate (PRR) of 40 MHz and average power of 40 mW. Initially, we plan to reduce the PRR to 1 MHz using an Acousto-Optic Modulator (AOM) with an insertion loss of 10 dB. The pulses are then stretched, pre-amplified in a double-pass Thulium (Tm) fiber configuration to compensate losses, and subsequently directed to a multi-pass solid-state Holmium:Yttrium Lithium Fluoride (Ho:YLF) amplifier before final pulse recompression (Figure 1).

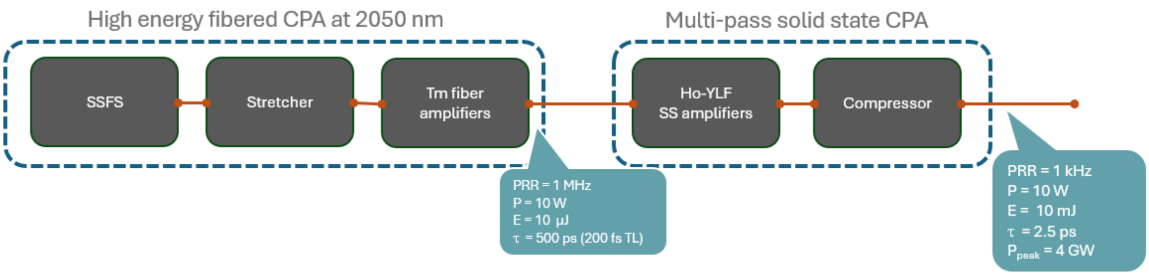

Figure 1: Hybrid CPA system design

Based on our extensive testing and experimental measurements, Ho:YLF crystals demonstrate remarkable gain capabilities in solid-state amplifier configurations. Our experiments revealed gain values exceeding 150 in a double-pass arrangement when pumped with 50 W of power and seeded with a broadband seed of 100 mW average power input at 40 MHz pulse repetition rate.

To optimize the solid-sate system, we developed and experimentally validated a two-dimensional rotationally symmetric amplifier model [2] that accurately predicts output power for both single and double-pass configurations across various seed inputs and pump intensities (figure 2). While currently limited to CW narrow band seed cases, this model allows optimizations for crystal geometry, doping %, and pump and seed configurations, with future plans to extend its capabilities to simulate broadband pulsed seed applications.

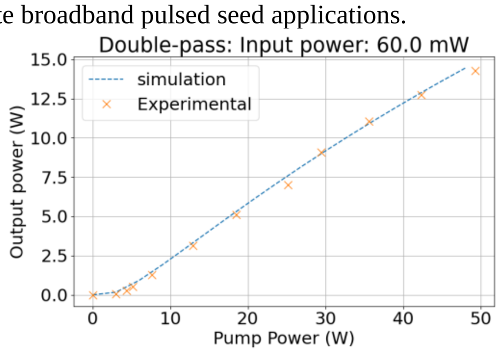

Figure 2: Measured (x) and simulated (dashed line) amplifier output power vs pump power, for a narrow band CW seed of 60 mW input power.

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Micro drilling of thin glass with GHz-bursts of femtosecond pulses for flat panel displays and microelectronics manufacturing

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Abstract

Over the past few years, the use of GHz-bursts of femtosecond pulses emerged as an efficient technique for crack-free and chemical-free high aspect ratio micro drilling of transparent dielectrics materials [1,2]. Indeed, the inter-pulse delay within the burst (0.8 ns) is shorter than the heat relaxation time of the target material, so a gentle heat accumulation occurs during each burst, improving the local ductility of the material and leading to a highly efficient drilling mechanism. In this study, we investigate the potential of this innovative technique for blind and through hole drilling in Corning ® Eagle XG glass (Alkaline earth boro-aluminosilicate). This glass is considered as the most widely used and trusted glass for thin, light and large-size display panel manufacturing. The glass composition includes no added heavy metals, reducing the environmental impact and health hazards of manufacturing and thinning. Eagle XG glass presents also a high interest for interposers in microelectronics. These devices are used as interconnecting layers between components in 3D printed board chip manufacturing. Our motivation is to develop and optimize a new technique for through glass via (TGV) of Eagle XG glass. Investigated parameters are the burst repetition rate, the fluence, the number of pulses in the burst, the numerical aperture, and the pulse duration. Spatial beam shaping will be also considered.

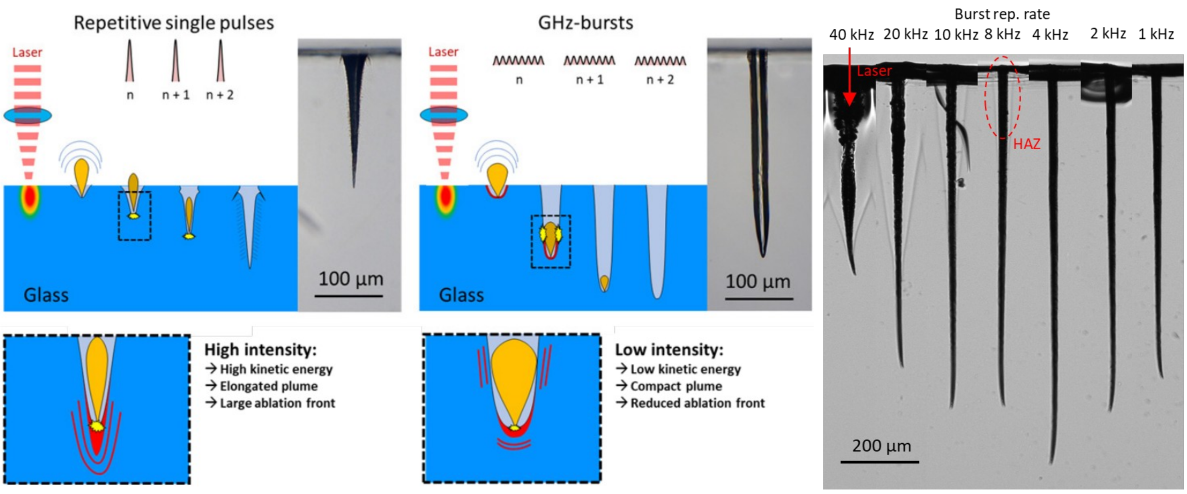

Fig. 1 (left) Schematic representation of the drilling process in the repetitive single pulse regime and in the GHz-burst mode [3]. (right) Micro drilling of Eagle XG glass at 1.28 GHz, heat affected zone and crack appearance with increasing burst repetition rate.

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