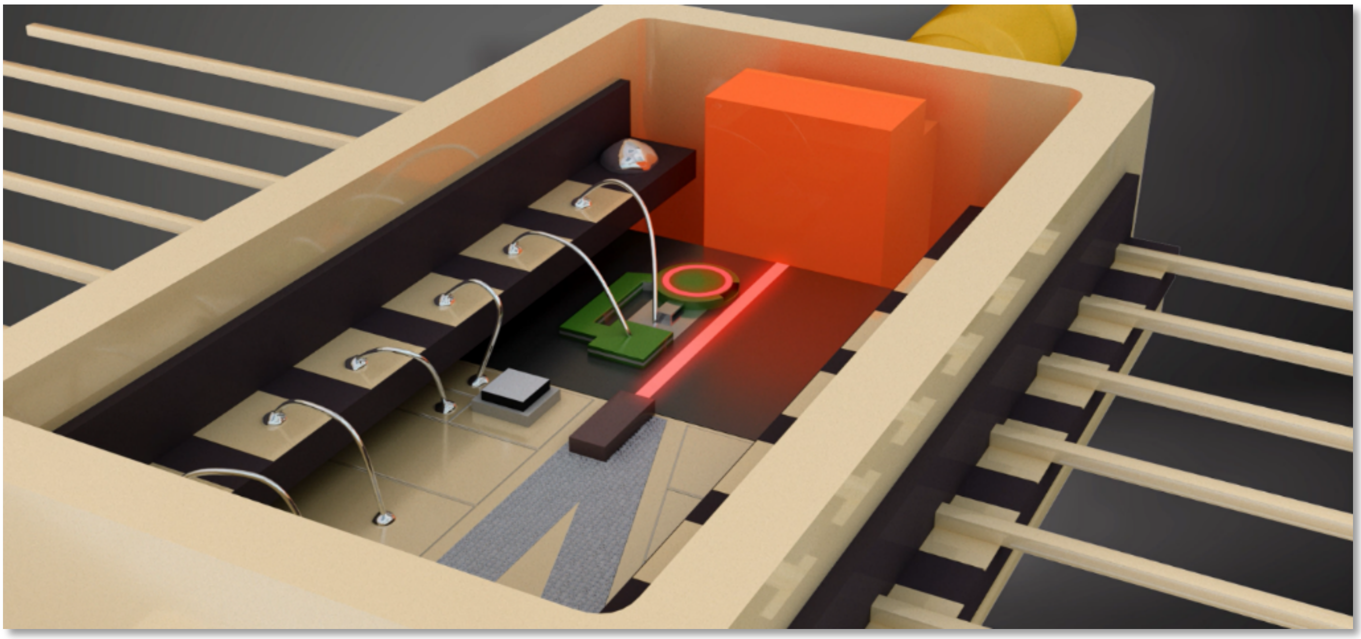

Narrow linewidth frequency agile integrated photonic lasers for space

Executive Summary

Early technology development

DISCOVERY IDEAS OPEN CHANNEL ETD ACTIVITIES EVALUATION 2021-11

Affiliation(s): DEEPLIGHT SA

Activity summary:

Deeplight aims to revolutionize laser technology by developing integrated lasers for quantum applications. Current lasers are often bulky and expensive, hindering mass production. Deeplight's approach, using Si3N4-based integrated photonics, promises compact, low-cost lasers with precise wavelength control. They achieved record-low phase noise in the near-IR, extended to the visible range. The lasers exhibit high power, low linewidths, and rapid frequency agility. Prototypes include lasers at 1550 nm, high-speed modulated lasers, sub-micron lasers with MEMS actuators, widely tunable lasers, and a blue laser. These advancements hold potential for quantum technologies, sensing, and optical atomic clocks.

→ THE EUROPEAN SPACE AGENCY

Publishing Date: 12/01/2021
Contract Number: **ESA STAR AO 2-1828/22/NL/GLC/ov**
Implemented as **ESA EXPRESS PROCUREMENT (EXPRO) / RESTRICTED COMPETITIVE**

ESA Discovery & Preparation
From breakthrough ideas to mission feasibility. Discovery & Preparation is laying the groundwork for the future of space in Europe
Learn more on www.esa.int/discovery
Deliverables published on https://nebula.esa.int

FEARLY TECHNOLOGY DEVELOPMENT CONTRACT REPORT

No ESA Contract Report will be accepted unless this sheet is inserted at the beginning of each volume of the Report.

ESA Contract No: **4000137900/22/NL/GLC/ov**	**SUBJECT**: Narrow linewidth frequency agile integrated photonic lasers for space	**CONTRACTOR**: DeepLight SA
* ESA CR( )No:	No. of Volumes: **....** This is Volume No: **....**	CONTRACTOR'S REFERENCE: Milestone 3 Report 01.05.2022 – 31.10.2023

ABSTRACT:

See report below

The work described in this report was done under the ESA Contract. Responsibility for the contents resides in the author or organization that prepared it.

Names of authors: Vladimir Shadymov, Andrea Bancora, Andrey Voloshin, Jean Berney

** NAME OF ESA MANAGER: DIV: DIRECTORATE:	** ESA BUDGET HEADING:

Deeplight SA

Vladimir Shadymov, Andrea Bancora, Andrey Voloshin, Jean Berney

Early Technology Development:

Narrow linewidth frequency agile integrated photonic lasers for space

Contract number: **ESA STAR AO 2-1828/22/NL/GLC/ov**

Milestone 3

Executive Summary (Deliverable 6)

Covering the period: 01.05.2022 – 31.10.2023

This document is the Executive Summary (Deliverable 6) and reports on the activities and results during the whole period from 01.05.2022 to 31.10.2023.

Executive summary (Deliverable 6)

Lasers are ubiquitous in science and technology, with applications ranging from optical communications and quantum technologies to metrology and sensing and to life sciences and medical diagnostics. Lasers are equally at the heart of numerous emerging quantum technologies, ranging from control of trapped ions for quantum computing, Rydberg atoms for field sensors, lasers to interrogate atoms for the world's most precise atomic clocks based on laser cooled atoms in lattices. For wider deployment of such quantum technologies in the field, airborne or in space, the miniaturization of high-performance narrow linewidth laser sources is imperative.

However, most commercially available lasers are still based on legacy technical schemes, requiring manual assembly from discrete components (fibers, diffraction grating, mirrors) or utilizing rather basic III-V semiconductor structures. These devices are either bulky and expensive – and thus prevent the adoption of novel types of photonic systems for mass production and high-volume applications. The advent of advanced photonic integration platforms such as silicon photonics has led to very compact chip-based lasers. This evolution was mainly driven by high-speed communications in exa-scale data centers, and these sources lack wavelength coverage or precise frequency tunability required for the challenging quantum and sensing applications such as quantum radio-frequency sensors and lasers for optical atomic clocks. For example, in the context of Doppler laser cooling, it is essential for the laser's linewidth to be significantly smaller than that of the atom to achieve low temperatures. To achieve optimal performance, it is crucial to have a laser with a well-defined, stable, and precisely adjustable absolute wavelength. For mass adoption of quantum technologies such lasers should have a compact footprint and be low-cost.

We aim at establishing a new class of integrated lasers, that can address the UV to visible wavelength range from the blue (400 nm), addressing key wavelength relevant to laser cooled atoms and trapped ions. Si_3N_4 based integrated photonics laser have demonstrated record low phase noise and frequency agility in the near IR – beyond the performance of fiber lasers. In this project Deeplight extended this approach into the visible, and creates a platform combines ultra-low-loss Si_3N_4 photonic circuits with advanced piezoelectrical thin film tuning actuators and with III-V gain elements. The devices will offer high output powers, Hz-level and kHz-level laser linewidths, and unprecedented frequency agility with nanosecond response times.

- We demonstrated fully packaged hybrid integrated lasers at 1550 nm with spiral cavities demonstrating the Lorentzian linewidth 10 dB lower that fiber lasers, e.g. the frequency noise is 10 Hz^2/Hz at 10 kHz offset.
- We demonstrated fully packaged hybrid integrated lasers with 1.5 GHz and 250 MHz spiral cavities and AlN actuators for high speed modulation of ulta-low noise lasers, which is ideal for air- and space-borne coherent sensing, e.g. free-space coherent optical communication applicaitons.
- We demonstrated for the first time a sub-micron laser (compatible with laser diodes from 780 nm to 1000 nm) with monolithically integrated MEMS piezoelectric actuators for fast and precise laser frequency control. It offers >10 MHz laser frequency actuation bandwidth with the frequency excursion range of >1 GHz. The frequency tuning efficiency was 35 MHz/V. We demonstrated the linear chirp of the laser with sweep rates up to 500 kHz. Fully packaged devices with kHz-level linewidth are available for testing.
- We demonstrated and packaged a hybrid integrated widely tunable laser around 900 nm with 11 mW of output power and kHz-level linewidths. We demonstrated samples with >30 mW of output power in a single mode fiber optimizing the Si_3N_4 platform and mode converters, further

optimization is possible to achive the level of power of 100 mW. Fully packaged devices are available for testing.

- We demonstrated the hybrid integrated blue laser with 100 kHz linewidths. We demonstrated the frequency-agility via chirping the laser frequency with sweep rates up to 500 kHz.
- We tested the prototypes with early adopters of the technology and disseminated the results of the project. Deeplight planned the extensive exploitation with partners and breakthrough demonstrations in quantum technologies and compact demonstrators.