GALACTIC - High Performance Alexandrite Crystals and Coatings for High Power Space Applications

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Spaceborne Earth observation via LIDAR instruments requires new laser systems to gain deeper insight in large-scale atmospheric dynamics, improve the climate modelling and enhance the monitoring of the planet's surface regarding the impact of climate change. Space-qualified Alexandrite crystals with optical interference coatings optimized for high laser-induced damage thresholds as laser-active media can overcome current limitations by providing wavelength tunability, short pulses and high optical efficiency if pumped by state-of-the-art laser diodes [1].

Project overview

The consortium:
- **Laser Zentrum Hannover e.V.** (Germany) → Project coordinator, laser development
- **Optomaterials S.r.l.** (Italy) → Alexandrite crystal manufacturing
- **Altechna Coatings** (Lithuania) → Coating deposition, surface treatment

Project goals:
- Push the Alexandrite laser crystal technology within the EU up to Technology Readiness Level (TRL) 6
- Establish a European-based supply chain for high-quality functionally coated Alexandrite laser crystals

Fig. 1: Enhance standard Alexandrite crystals (currently TRL 4) to achieve space-qualified, high-quality components with TRL 6.

Crystal growth and machining

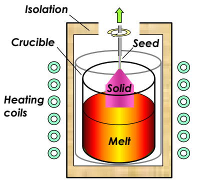


Fig. 2: Czochralski method

Improvement of
- crystal growth parameters
- machining process (extraction, cutting, shaping, grinding)
- optical polishing

Measurement of
- doping concentration
- mechanical specifications (dimensions, perpendicularity, parallelism, bevels)
- surface quality (scratch-dig)
- surface flatness and wavefront distortion
- spectral properties (absorption, transmission, XRD and Raman)

Fig. 3: Alexandrite crystal boule

Optical interference coatings

Fig. 4: Schematic diagram showing the plasma etching process (left) performed with the ClusterLine RAD sputter platform (right).

Optimization of
- coating design
- coating process and materials
- surface treatment (ultrasonic cleaning, plasma etching)

Verification via
- transmission and absorption measurements
- tape-lift test
- LIDT test (R-on-1 and raster scan)

HR / HT coating	DAR coating
HR > 99.5 % @ 760 ± 20 nm HT > 95 % @ 638 ± 20 nm	AR < 1 % @ 638 ± 20 nm AR < 0.25 % @ 760 ± 20 nm

Table 1: Coating specifications for two different crystal parts: a) HR/HT on S1, DAR on S2, b) DAR on S1 and S2, AOI = 0° each.

Laser demonstrator setups

Two laser demonstrators are derived from possible Earth observation space missions:
- **LIDAR for atmospheric sensing → System 1**
- **Altimetry, vegetation monitoring → System 2**

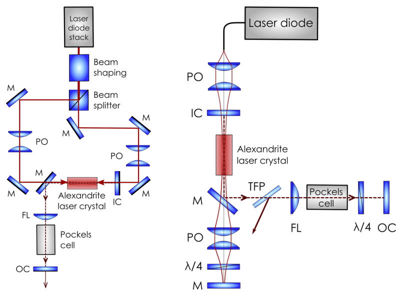


Fig. 5: Principle sketch of diode-pumped Alexandrite laser setups: System 1 (left), System 2 (right). PO: Pump Optics, M: Mirror, TFP: Thin Film Polarizer, IC/OC: Input/Output Coupler, FL: Focusing Lens

Laser parameters

	System 1 high E_{puls} / low f_{rep}	System 2 low E_{puls} / high f_{rep}
Pulse energy E_{puls}	> 3 mJ	≥ 200 µJ
Pulse duration	≈ 100 ns	< 10 ns
Repetition rate f_{rep}	50-500 Hz	≥ 5 kHz
Laser wavelength	750-770 nm	750-770 nm

Table 2: Intended output parameters of the two demonstrators.

Qualification test campaign

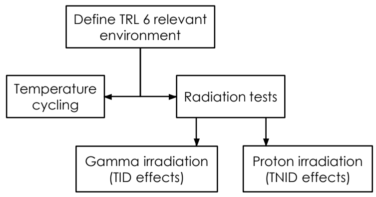


Fig. 6: Environmental test campaign planned for TRL 6 qualification. TID: Total Ionizing Dose, TNID: Total Non-Ionizing Dose

Thermal cycling

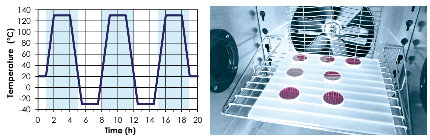


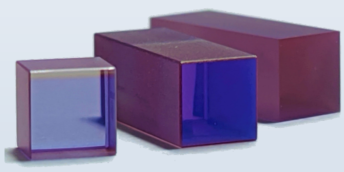
Fig. 7: Schematic test sequence (left), climate chamber (right).

Parameters of temperature durability test:
- Test range: -30 °C to +130 °C
- Hold times: 2 h
- Rate of change: < 2.2 K/min
- No. of cycles: 3 hot and 2 cold cycles
- Ambient pressure, non-condensing env.

Irradiation testing

Gamma irradiation:
- Dose level: 10 krad, 30 krad
- Dose rate: 4 krad/h

Proton irradiation:
- Flux: 10^{12} protons/cm² with 8 and 70 MeV equivalent protons



Alexandrite test crystals

The Horizon 2020 project GALACTIC [2, 3] will pass through the following four steps to setup the European-industry-based supply chain for space-qualified Alexandrite crystals:
- Develop advanced Alexandrite crystal growth and surface treatment processes
- Design and characterize advanced optical interference coatings
- Demonstrate the crystal performance in typical laser configurations
- Qualify the coated crystals according to TRL 6

Enable non-dependence of Europe on Alexandrite laser crystal and coating technologies for space applications.

References:

[1] M. J. Damzen et al., Progress in diode-pumped alexandrite lasers as a new resource for future space lidar missions, ICSO 2014

[2] Cordis Europa, Horizon 2020, Fact Sheet, https://cordis.europa.eu/project/id/870427

[3] GALACTIC website: https://h2020-galactic.eu/

Project partners:

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