European supplier based Alexandrite crystals and coatings for high power space applications

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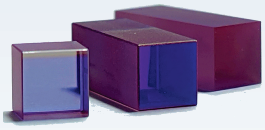
Spaceborne Earth observation via LIDAR instruments requires new laser systems to gain deeper insight in large-scale atmospheric dynamics, improve the climate modelling and enhance the monitoring of the planet's surface regarding the impact of climate change. Laser systems equipped with space-qualified Alexandrite crystals as laser-active media are promising alternatives to currently used sources due to the ability to provide wavelength tunability, short pulses and high optical efficiency if pumped by state-of-the-art laser diodes [1].



GALACTIC: Project overview

The consortium:

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

Achievements (see [2] and [3] for details):

- Technology Readiness Level (TRL) of the Alexandrite laser crystal technology within the EU increased from 4 to 6
- Solely European supply chain for high-quality, functionally coated Alexandrite laser crystals established
- Non-dependence of Europe on Alexandrite laser crystal and coating technologies for space applications enabled

TRL 4 → **TRL 6**

Fig. 1: Standard Alexandrite crystals (initially TRL 4) enhanced to achieve space-qualified, high-quality components with TRL 6.

Crystal growth and machining

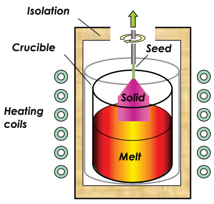


Fig. 2: Czochralski growth method.

Improvement of

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

Optical interference coatings

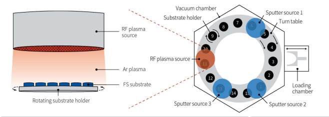


Fig. 4: Schematic sketch showing the plasma etching process (left) performed with the ClusterLine RAD sputter platform (right).

HR / HT coating	DAR coating
HR > 99.5 % @ 760 ± 20 nm, AOI = 0° HT > 95 % @ 625-645 nm, AOI = 0-16°	AR < 1 % @ 638 ± 20 nm, AOI = 0-16° AR < 0.25 % @ 760 ± 20 nm, AOI = 0°

Table 1: Coating specifications for two different crystal parts: a) OIC2: HR/HT on S1, DAR on S2, b) OIC1: DAR on S1 and S2.

Laser demonstrator setup

Our laser demonstrator is derived from possible Earth observation space missions:

- **Altimetry, vegetation monitoring**

Laser Parameter	Target value	Achieved
Pulse energy	≥ 200 µJ	> 650 µJ
Pulse duration	< 10 ns	2.8 ns
Repetition rate	≥ 5 kHz	5 kHz
Laser wavelength	750-770 nm	755 nm

Table 2: Parameters of the laser demonstrator [4,5].

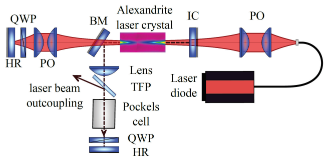


Fig. 3: Principle sketch of cavity-dumped Q-switched Alexandrite laser. HR: high-reflecting mirror; QWP: quarter-wave plate; PO: pump optics; BM: bending mirror; IC: input coupling mirror; TFP: thin film polarizer (see [4] for details).

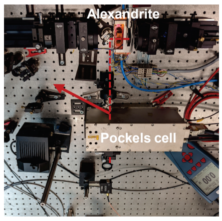


Fig. 4: Picture of the setup in laboratory.

Environmental test campaign

Environmental testing:

- Proton and gamma irradiation
- Thermal cycling

Verification:

- Functional laser tests
- Transmittance
- LIDT
- Tape-lift

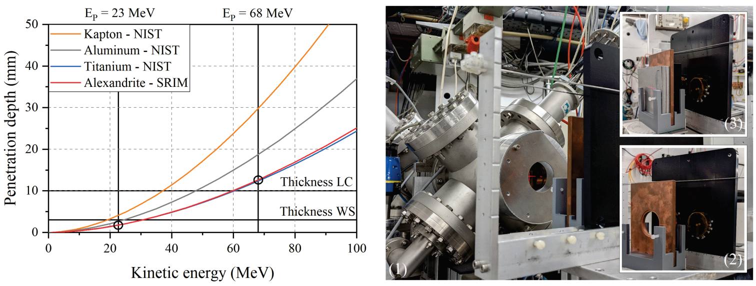


Fig. 5: Left – Penetration depths of high-energetic protons within Alexandrite (SRIM calculations from HZB), Kapton, aluminum, and titanium (NIST data). Right – GALACTIC samples aligned in front of the scientific proton beamline at HZB (1) for irradiation with 68 MeV (2) and 23 MeV protons (3). LC: laser crystal; WS: witness sample. Figures from [5].

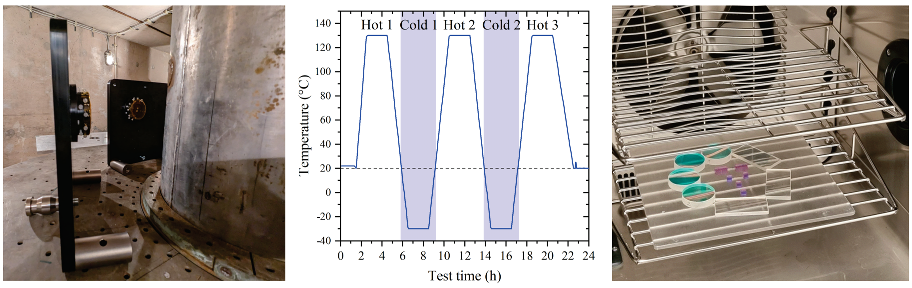


Fig. 6: Left – Samples in front of Co-60 source at HZB. Middle – Thermal cycling test sequence. Right – Alexandrite crystals in climate chamber at Altechna. Figures from [5].

- **Proton irradiation with 68 MeV and 23 MeV protons – proton flux: 10^{11} protons/cm²; proton flux rate: $8{\cdot}10^{7}$ protons/(cm² s) – and gamma irradiation with 10 krad and 30 krad – dose rate: 4 krad/h – at Helmholtz-Zentrum Berlin (HZB)**
- **Thermal cycling – temperature range: -30°C to +130°C – in climate chamber at Altechna**

Verification test results

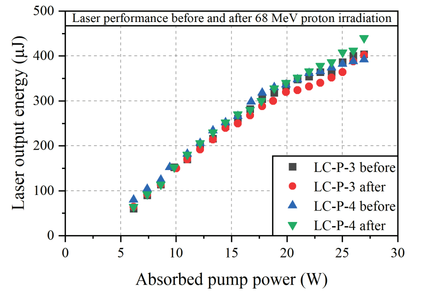


Fig. 7: Laser output energy as a function of the absorbed pump power before and after 68 MeV proton irradiation (samples LC-P-3 and -4) [5].

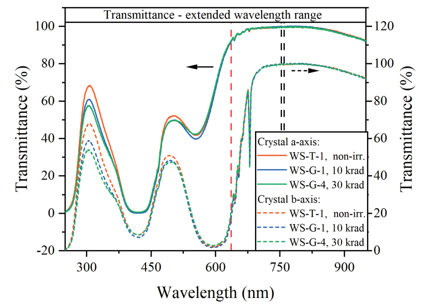


Fig. 8: Transmittance of non-irradiated (WS-T-1) and gamma irradiated samples (WS-G-1 and WS-G-4). Red dashed line: pump wavelength; black dashed line: laser wavelength range. Figure from [5].

No laser-relevant degradation of functionally coated Alexandrite crystals due to environmental testing observed

References:

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[2] Cordis - EU research results: https://cordis.europa.eu/project/id/870427
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[4] S. Unland, et al., "High-performance cavity-dumped Q-switched Alexandrite laser CW diode-pumped in double-pass configuration," Opt. Express 31 (2023)
[5] R. Kalms, S. Unland, et al., "Space radiation testing and thermal cycling of functionally coated Alexandrite laser crystals," Opt. Mater. Express 14 (2024)

Project partners:

Optomaterials, Altechna

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