Fraunhofer
IOF

Fraunhofer Institute for Applied Optics and Precision Engineering IOF

Optical Instrumentation

Photonics for Aviation and Space

Content

Experience in optical instrumentation for space

Fraunhofer IOF develops high-performance optical systems and components for demanding applications in aviation and space.

We provide end-to-end solutions, from full system design and ultra-precise manufacturing through space qualification and validation to customer-specific prototypes and small-series production. Our expertise is focused on ultra-lightweight, long-term stable optical components and systems that withstand the harsh conditions of launch and in-orbit operation.

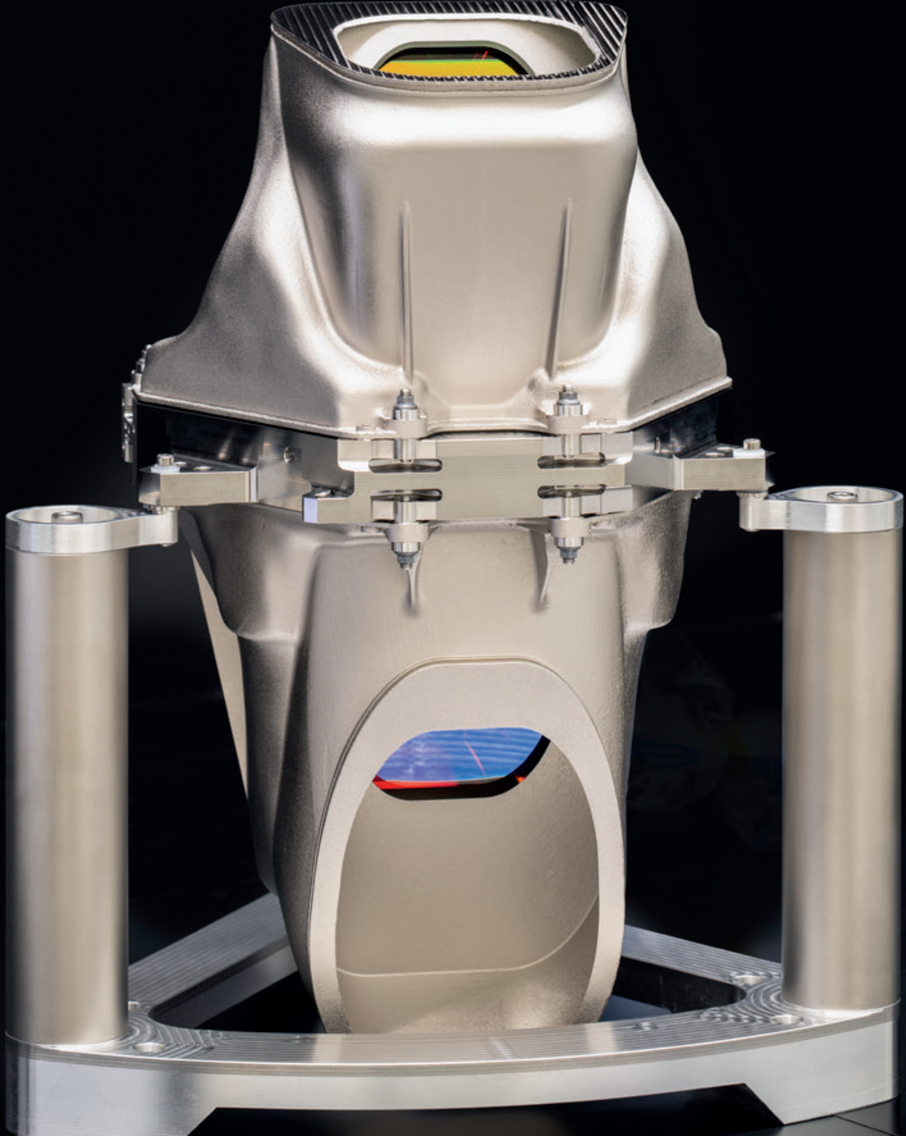
Our key competencies include athermal optical designs, fiber-based laser systems for demanding environments, advanced diffraction gratings, and innovative adhesion-free joining and assembly technologies. This enables our customers to reduce system mass, increase stability, and improve overall mission reliability and performance.

Cover: CubeSat equipped with a telescope for quantum key distribution.

Fraunhofer IOF operates state-of-the-art facilities for micro-optics, ultra-precision machining, precision engineering and assembly, optical coating, and surface and system characterization. We develop optical technologies in line with ECSS (European Cooperation for Space Standardization) standards for European space activities. Our development and manufacturing processes are designed to ensure clear interfaces and seamless collaboration with partners from science and industry.

As a founding member of the Fraunhofer Alliance AVIATION & SPACE, Fraunhofer IOF is a trusted partner for the development of cutting-edge optical components and systems. The following pages provide an overview of our core competencies for aviation and space.

Right: An enclosed disperser element for the CO2M mission, designed to split reflected light from Earth into its spectral components for high-precision measurements.



Project participation

During the last years, the Fraunhofer IOF developed a variety of optical systems in close cooperation with our customers. The institute was involved In many projects related to space- and ground-based optical instrumentation.

CODAG (Cosmic Dust Aggregation Experiment) – light-weight microscope support allowing adjustment and synchronous motion of two microscopes.

RapidEye – TMA mechanical design, manufacturing of spherical and aspherical mirrors, and assembly of the TMA telescopes.

Piston Mirror manufacturing and assembly for the **Large Binocular Telescope (LBT)**.

ESTEC project "Angle resolved light scatter measurement system".

EnMAP project – ultraprecise metal mirrors with protected silver and sputtered gold (VIS-NIR-IR) for the Environmental Mapping and Analysis Program.

ESA's GAIA satellite – RVS grating development and flight model fabrication, test CGH for the primary telescope mirror.

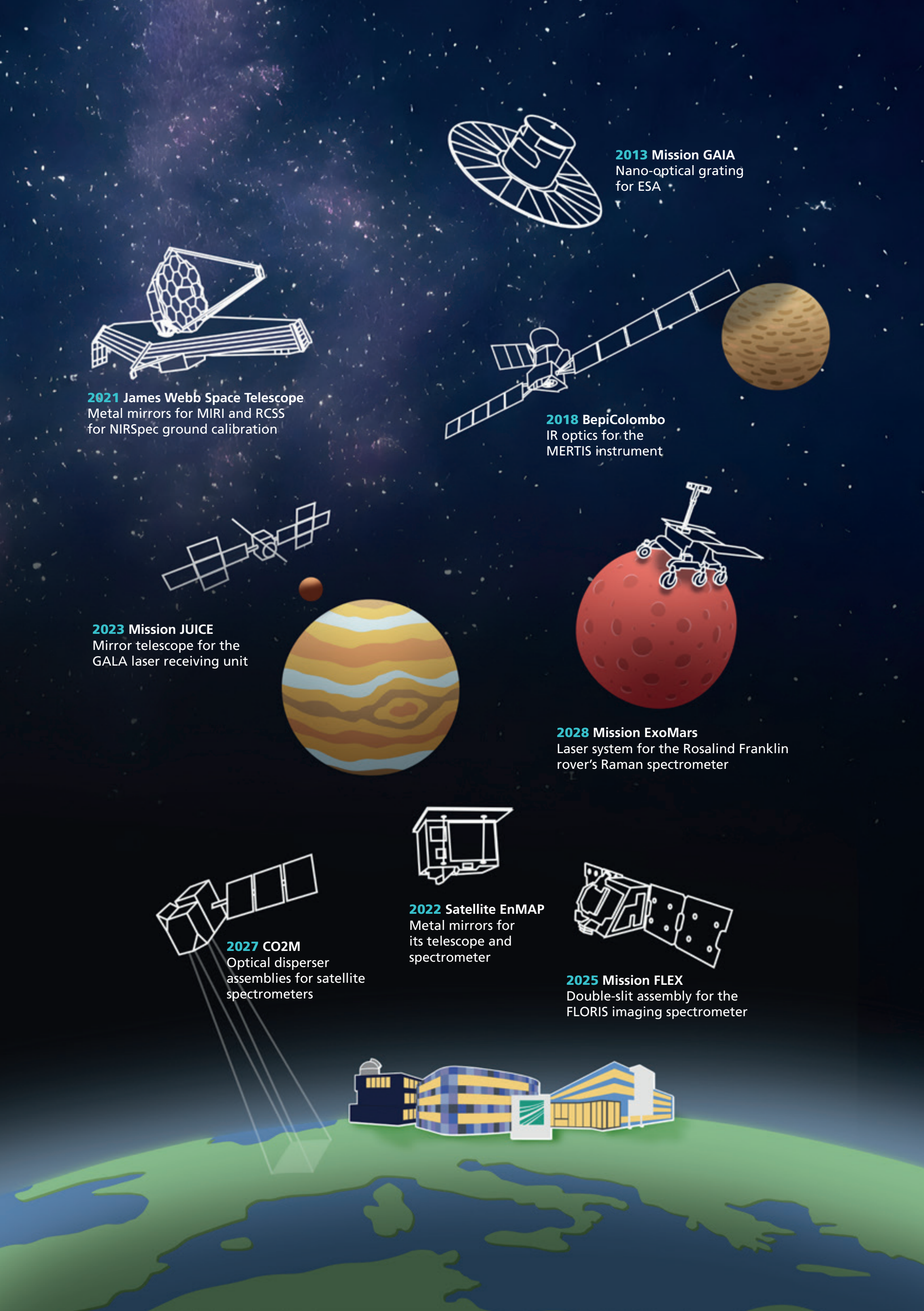
James Webb Space Telescope – light-weighted metal mirrors for MIRI (Mid InfraRed Instrument).

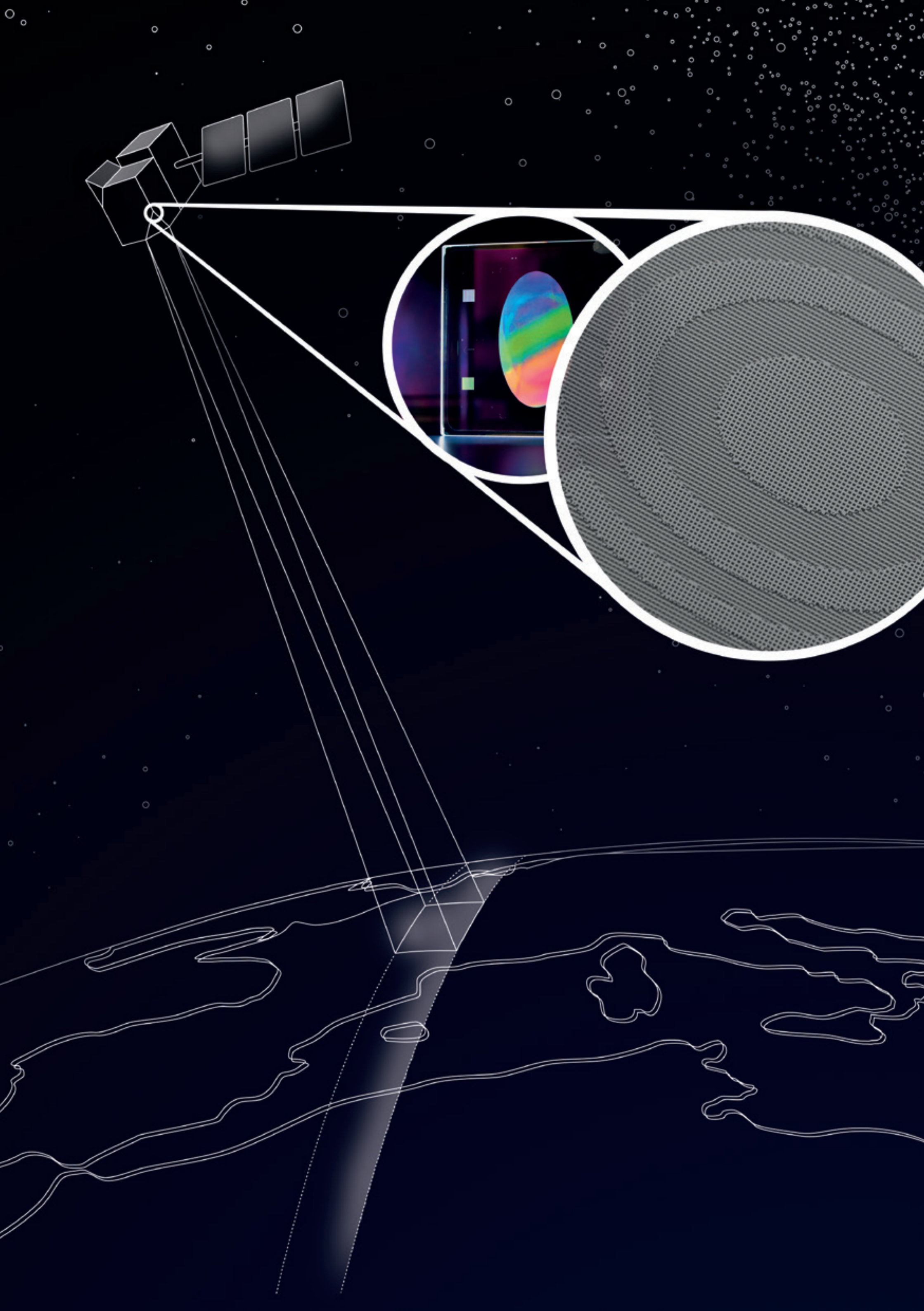
Sentinel 4 – grating design study and demonstrator fabrication for the UV/VIS- and NIR-spectrometer channel.

DESIS – system development of the hyperspectral Earth observation instrument for the DLR Earth Sensing Imaging Spectrometer.

GALA – development of the mirror telescope for the GALA laser altimeter on ESA's JUICE mission.

CO2M – development of dispersers for ESA's Copernicus Anthropogenic CO2 Monitoring (CO2M) mission.


2013 Mission GAIA
Nano-optical grating for ESA
2021 James Webb Space Telescope
Metal mirrors for MIRI and RCSS for NIRSpec ground calibration
2018 BepiColombo
IR optics for the MERTIS instrument
2023 Mission JUICE
Mirror telescope for the GALA laser receiving unit
2028 Mission ExoMars
Laser system for the Rosalind Franklin rover's Raman spectrometer
2022 Satellite EnMAP
Metal mirrors for its telescope and spectrometer
2027 CO2M
Optical disperser assemblies for satellite spectrometers
2025 Mission FLEX
Double-slit assembly for the FLORIS imaging spectrometer



Left: Schematic representation of an Earth observation satellite that uses nanostructured optics to perform spectral analysis of key Earth climate parameters.

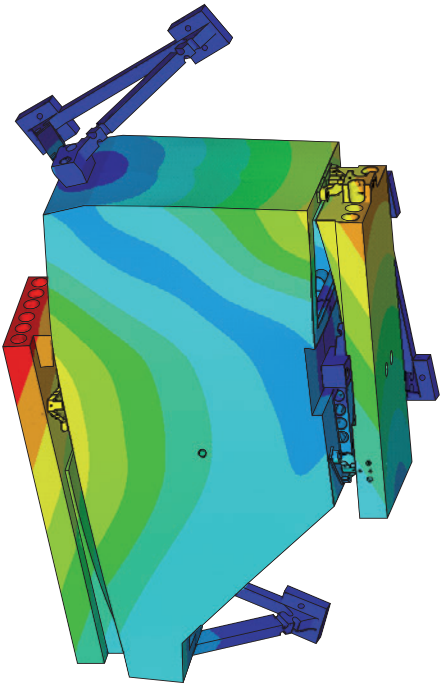
Shaping the future of aviation and space optics

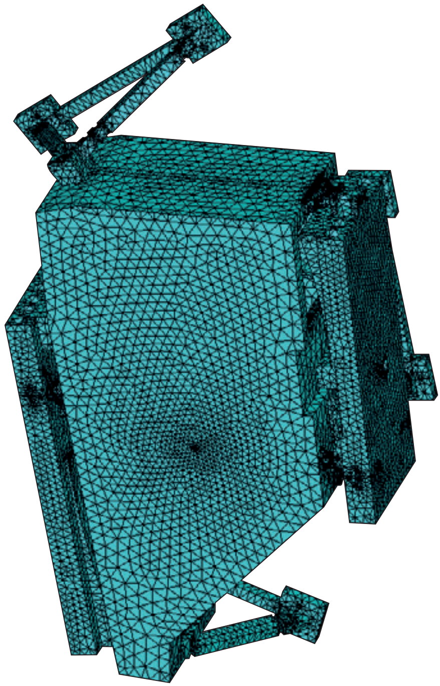
Fraunhofer IOF is your development partner for innovative optical solutions in aviation and space – from first mission ideas to qualified hardware in orbit. Building on our proven heritage in international space missions, we combine scientific excellence with industrially robust processes to turn ambitious concepts into reliable instruments and subsystems.

Technology modules presented on the following pages form a comprehensive toolkit for your next mission: optical design and simulation, advanced materials and additive manufacturing, ultra-precision machining and freeform optics, micro- and nano-structured elements, bonding and coating technologies, metrology and stray light analysis, system integration, laser and quantum technologies, as well as optical ground segment solutions. These building blocks can be tailored and combined to match your specific requirements – enabling lighter, more compact and more powerful instruments for future aviation and space applications.

Design and simulation

From early mission studies to flight-ready designs, Fraunhofer IOF provides end-to-end optical and opto-mechanical design and simulation for demanding air- and spaceborne instruments. We combine optical, mechanical, thermal and stray-light simulation to ensure that your payload delivers the required performance under real mission conditions.





The start for every missions

Tailored to your mission requirements, our engineers design refractive, reflective and diffractive systems – including gratings, freeform and micro-optics as well as fiber-based and quantum-optical components. Coupled structural, thermal and thermo-optical analyses enable us to predict alignment, stability and image quality from launch to in-orbit operation, turning your mission requirements into robust, manufacturable solutions.

- Optical system design
- Stray light analyses
- Structural & thermal FEM analyses
- Rigorous grating design

Top: Telescope for the GALA laser altimeter, which measures the heights and depths of planet's surface based on laser pulses.

Left: FEM model of the PREMIER telescope; first resonance mode oscillation at 319 Hz.

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Materials for space and astronomical application / instrumentation

Ultra-precise space optics start with the right choice of materials and coatings. Building on long-standing expertise in metal optics for space applications, Fraunhofer IOF develops and characterizes dimensionally stable substrates and technical layers for cryogenic and broadband space and astronomical instruments.

Stable substrates and functional layer combination for space optics

In an extensive testbed, Fraunhofer IOF performs environmental tests and thermal simulations to identify the optimal material combinations for each mission, balancing stability and weight while ensuring matched thermal expansion across all optical and mechanical interfaces. Proven material systems combine aluminum alloys such as Al6061 and Al-40Si with amorphous layers (a-Si, electroless NiP), enabling high-quality polishing and high surface accuracy from the IR to the EUV. Coefficient of thermal expansion (CTE)-matched combinations, for example Al-40Si with electroless NiP of tailored phosphorus content, minimize bimetallic bending in ultra-precise cryogenic mirrors. For next-generation space optics, ultra-lightweight aluminum mirrors are realized by selective laser melting and verified for dimensional stability.

- Materials for cryogenic optics
- Technical layers for polishing and shape correction techniques
- Dimensional stability analysis of materials via dilatometry and (cryo-) interferometry
- CTE analysis in a temperature range from -185 °C to 500 °C

Right: Thermal vacuum chamber.

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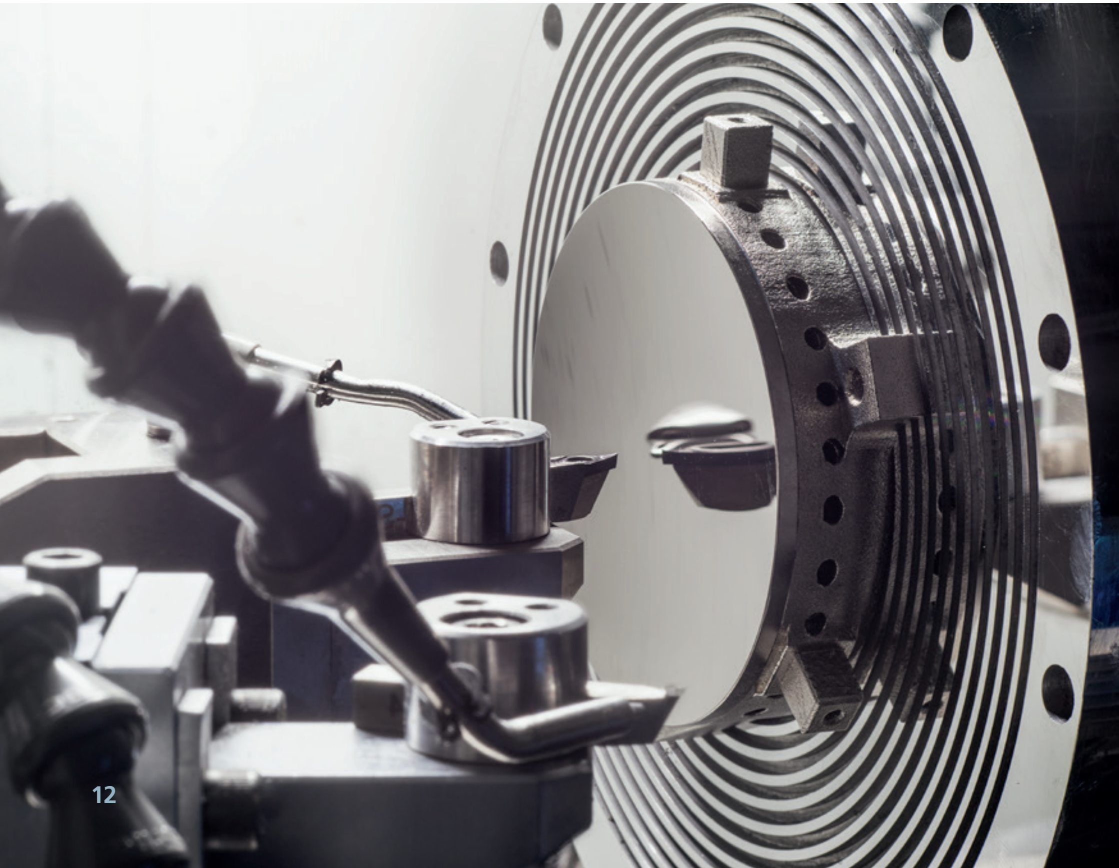
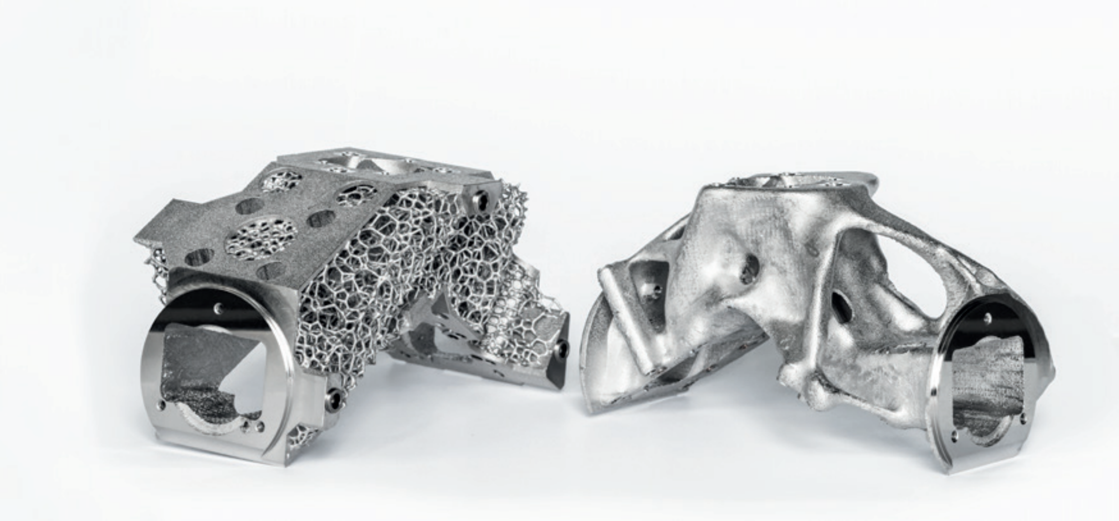
Additive manufacturing of high-performance metal optics and systems

Additive manufacturing enables Fraunhofer IOF to design and produce lightweight, high-performance metal optics and system housings for space and aviation applications. Using selective laser melting of aluminum-silicon alloys such as AlSi40, load-path-optimized mirror bodies and structures with integrated lattices, stochastic foams and internal cooling channels are manufactured. This design flexibility allows for weight reductions while maintaining stiffness and thermal stability.

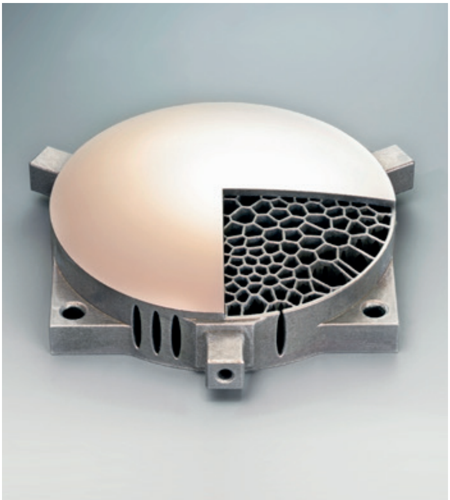




Purpose and Details

Process parameters and material combinations are optimized through studies and verified by CT inspection of internal geometries. The additively manufactured blanks are compatible with our established optical finishing chain: diamond turning, magnetorheological finishing and chemical-mechanical polishing. Combined with functional plating (e.g. NiP, Cu) and optical coatings (Al, Ag, Au) for the VIS–NIR–UV range, form errors below 150 nm PV and surface roughness below 1 nm RMS on apertures up to 150 mm are achieved.

- Weight reduction of up to 75% through topology optimization, lattice structures or stochastic foam structures
- Structural features down to 300 µm



Additively manufactured metal mirror with internal light-weight structure.

Top: Topology optimized housing.

Left: Lightweight metal mirror during ultra precision diamond turning.

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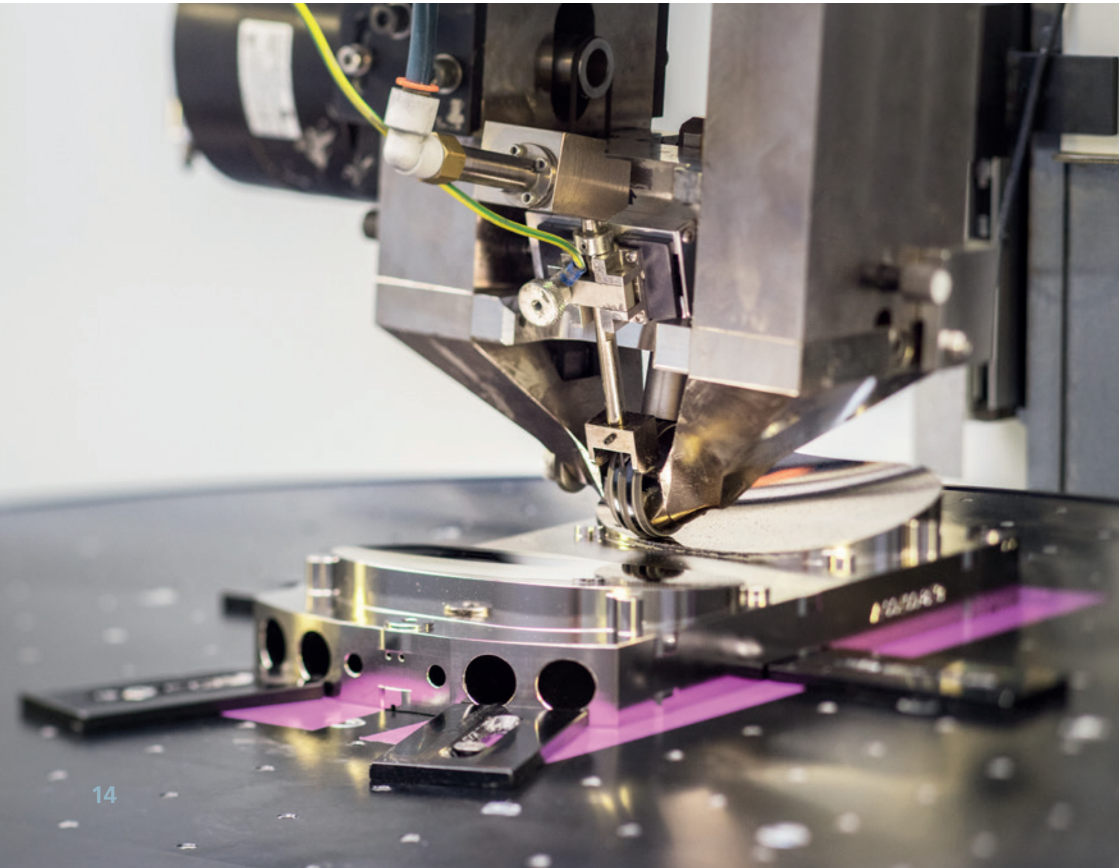
Ultra-precise machining

Fraunhofer IOF offers diamond-based ultra-precision machining for optical components and systems used in space and astronomy. Using state-of-the-art diamond turning, milling and ruling, it is possible tocreate rotationally symmetric and freeform surfaces on metals, glass and ceramics – ranging from plane, spherical, and aspherical mirrors to off-axis segments, gratings and micro-structured optical elements. Machine concepts with Slow and Fast Tool Servo enable complex geometries and apertures up to 1000 mm while maintaining nanometer-level surface quality.



The perfect finish

For applications at shorter wavelengths or with extreme requirements on wavefront accuracy and scatter, diamond machining is supplemented Magnetorheological Finishing (MRF). This deterministic polishing process corrects residual form errors and reduces roughness without compromising the underlying structures. In combination with precise lens centering, reference features and athermal material concepts, we deliver ultra-stable mirror systems and optics that can be aligned reliably and maintain their performance under launch loads, thermal cycling and operation in space.

- Ultra-precision machining based on diamond turning with Slow Tool Servo and Fast Tool Servo extension up to 1000 mm
- Diamond milling and ruling techniques
- MRF figuring of mirrors and lenses with apertures up to 1000 mm
- Highly precise individual mirrors / systems with reference features
- Patented light-weighting structures and athermal material blends
- Lens centering technology for high-quality optics

Top: Diamond turning of metal mirros.

Left: Shape correction of a metal mirror using magnetorheological finishing (MRF).

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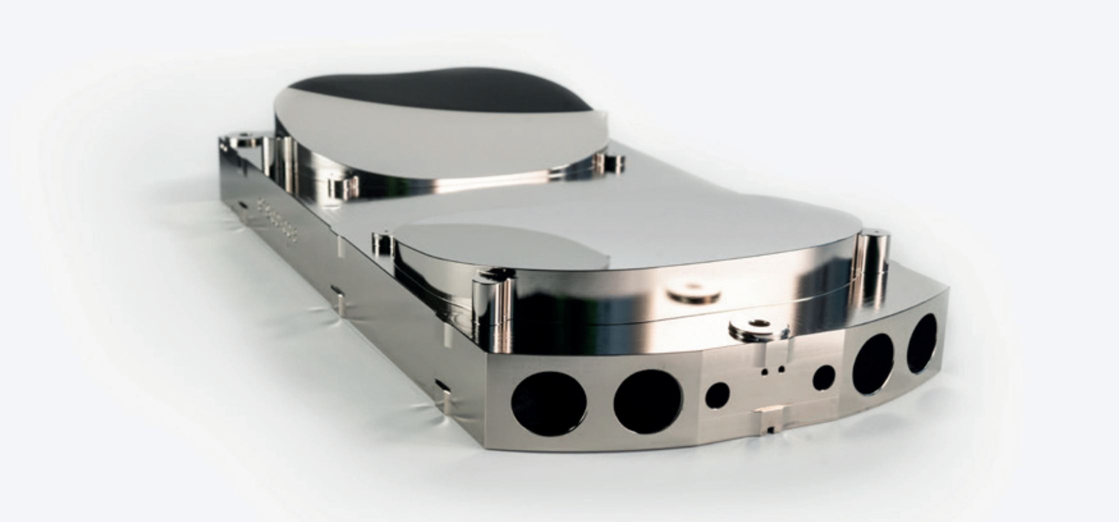
Freeform optical components and systems

Freeform optics enable a step change in optical performance for airborne and spaceborne instruments by combining superior image quality with drastic reductions in volume and mass. Drawing on more than a decade of experience and a dedicated technology platform, Fraunhofer IOF offers a complete development chain for freeform and aspheric metal optics: from optical and mechanical design through ultra-precision machining, coating, metrology, and system integration.



Freeform optics enable the manufacturing of compact optical systems

Optimized system design and tailored surface profiles enable folded beam paths, fewer elements, and additional functions within compact, robust housings – ideal for Earth-observation payloads, environmental monitoring, and micro- and nanosatellites. Our freeform systems cover a spectral range from VIS–UV to IR–NIR and support athermal designs based on materials such as AlSi50 and NiP. We routinely achieve shape deviations below 15 nm rms, surface roughness down to 0.4 nm rms, and apertures up to 1 m, with demonstrated space heritage up to TRL 9 (e.g. DESIS on the ISS).

- Closed production chain for metal optics for IR-NIR-VIS-UV
- for IR-NIR-VIS-UV
  - Shape deviation < 15 nm rms
  - Roughness < 0.2 nm rms
  - Dimensions up to 1 m
- Processing of different materials
- Athermal matching of AlSi50 and NiP
- Use up to TRL 9, e. g. telescope and spectrometer DESIS on ISS, developed in cooperation with DLR

Top: Freeform double-mirror substrate of a three-mirror-anastigmat telescope.

Left: Lightweight metal mirror ready to be integrated into optical system.

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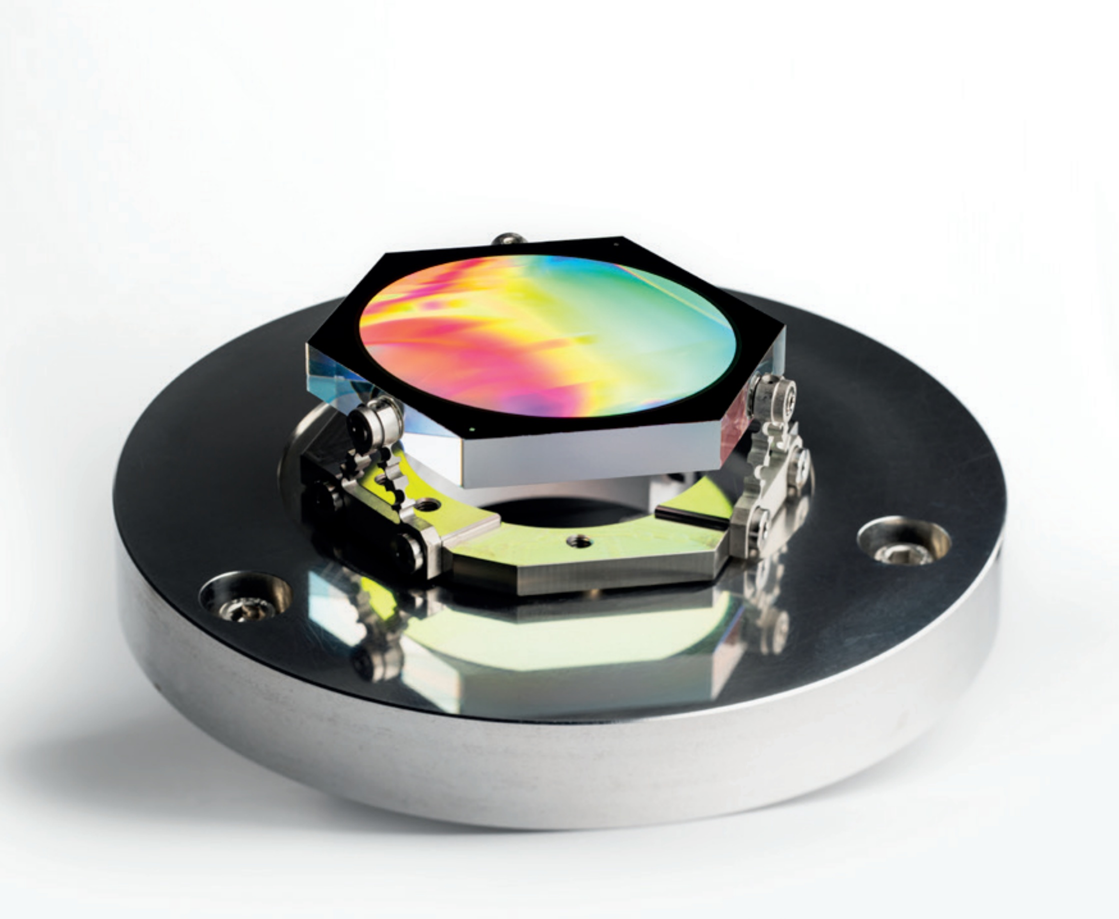

Micro- and nano-structured elements

Micro- and nanostructured optics are key components for next-generation space spectrometers and high-precision imaging instruments. Fraunhofer IOF develops and manufactures high-resolution diffraction gratings and computer-generated holograms (CGHs) that meet the stringent requirements of Earth observation and scientific missions such as GAIA, Sentinel 4, and CO2M.

Unlock incredible features

Spectrometer gratings from Fraunhofer IOF cover ultraviolet, visible, near infrared and short wave infrared ranges and can be optimized for low or high spectral resolution, high throughput and low polarization sensitivity. CGHs provide accurate wavefront control and are used for end-to-end testing and alignment of aspherical and freeform telescope mirrors. Using a dedicated lithography and etching platform that combines electron beam and grayscale photolithography with reactive ion etching and wafer scale replication, we realize tailored grating concepts with line densities up to 3500 lines per millimeter. Numerical design and optimization ensure high diffraction efficiency, excellent wavefront quality and minimized stray light for mission scenarios. Free standing slits and diffractive structures complete the spectrometer toolkit of Fraunhofer IOF.

- High performance spectroscopic gratings
- Advanced fabrication-optimized grating design
- Computer Generated Holograms for asphere and freeform testing
- CGH-based alignment features for UP machined aspherical and freeform mirrors
- Free-standing spectrometer slits

Top: Diffraction gratings on a glass substrate.

Left: The nanostructured grating for ESA's Copernicus Sentinel-4 instrument.

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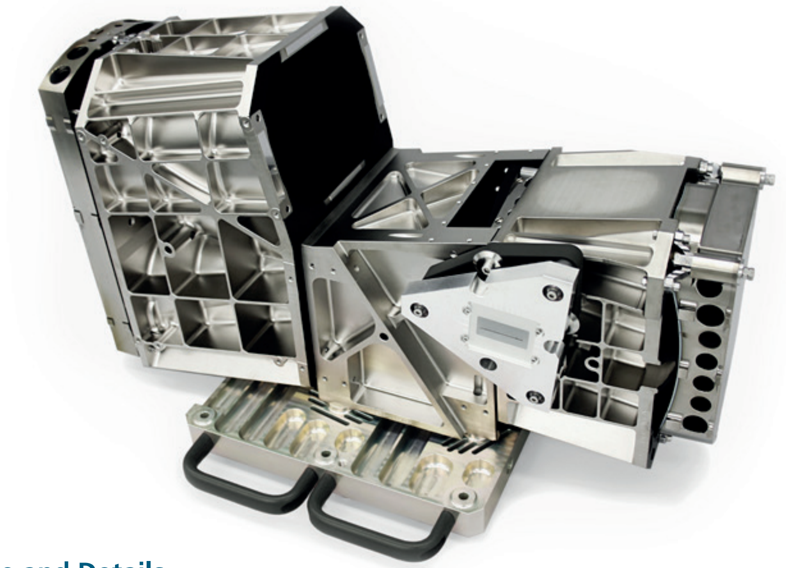
System integration

Modern optical instruments for aviation and space are not limited to optics and mechanics. They often include drive electronics for active elements, thermal management components, and actuators for precise motion control. The way these subsystems are integrated has a direct impact on optical performance, reliability, efficiency, and overall system cost.



Purpose and Details

Fraunhofer IOF develops and integrates optical systems based on metallic platforms. An increasing number of multi- and hyperspectral imaging instruments – such as space telescopes and spectrometers – rely on all-reflective metal optics to achieve high stability and robustness under harsh environmental conditions.

To reach diffraction-limited performance, each mirror in an imaging system must be assembled and aligned within very tight tolerances. We control the relative position of all optical elements with micrometer-level translational steps and tilt errors of only a few arcseconds. The integration concept of Fraunhofer IOF is based on an efficient "snap-together" alignment: reference features are diamond-turned in the same fabrication step as the corresponding mirror surfaces, ensuring a highly accurate and reproducible relationship between optical and mechanical interfaces.

- All-metal telescopes and spectrometers
- TMA telescopes for Earth observation
- Freeform based space optics
- Athermal optical systems
- Hybrid optical systems

Top: Imaging spectrometer for Earth observation.

Left: System integration of metal mirror.

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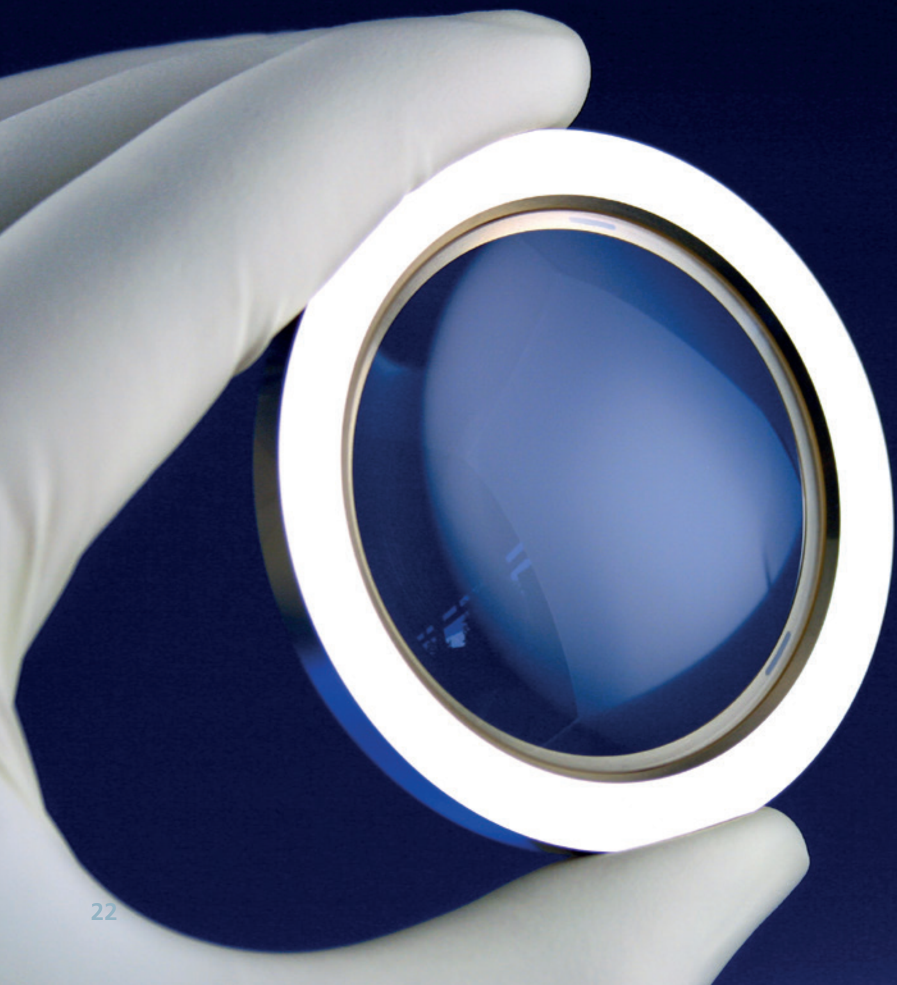
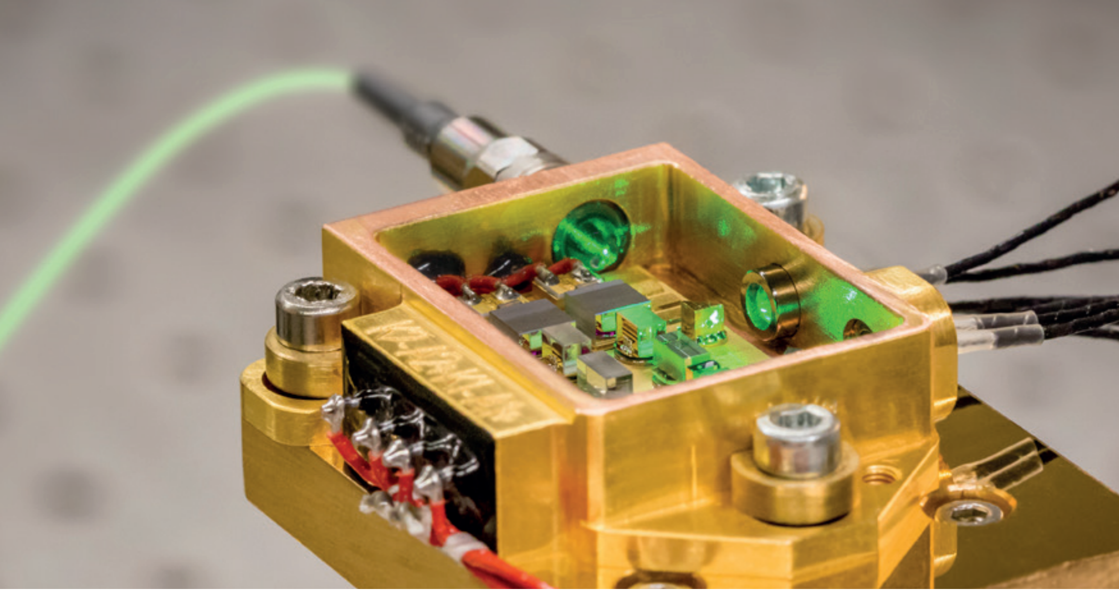
Packaging technologies

Packaging and joining technologies for optical and opto-mechanical systems in space and aviation must ensure highest accuracy and long-term stability under vacuum, radiation, vibration, and extreme temperature cycling. Our solutions enable sub-micron and arcsecond stability for demanding missions in Earth orbit and deep space.





Laser-based soldering technique

In addition to classical clamping and adhesive bonding, Fraunhofer IOF offers a versatile portfolio of bonding and laser-based soldering processes for components made of glass, metals, and ceramics. The focus is on high mechanical strength, minimal induced stress, highest optical transparency, and semi-monolithic, athermal assemblies. Using inorganic-metallic solders, the laser-based processes deliver superior stability compared to purely adhesive joints. We support our customers from joint design and FEM-based simulation through process optimization to the assembly and qualification of prototypes and small series. The joining technologies of Fraunhofer IOF have flight heritage in ESA missions such as Sentinel-2, and demonstrated their robustness under real space conditions.

- Solderjet Bumping for 3D components, sub-micron accuracy and stability
- Laser based thin film soldering for planar components
- Silicatic and plasma based bonding of planar components for highest transparency
- CO_2 laser based splicing and tapering of high power fiber components

Top: Steady-state laser module.

Left: Low-stress soldered lens in mount.

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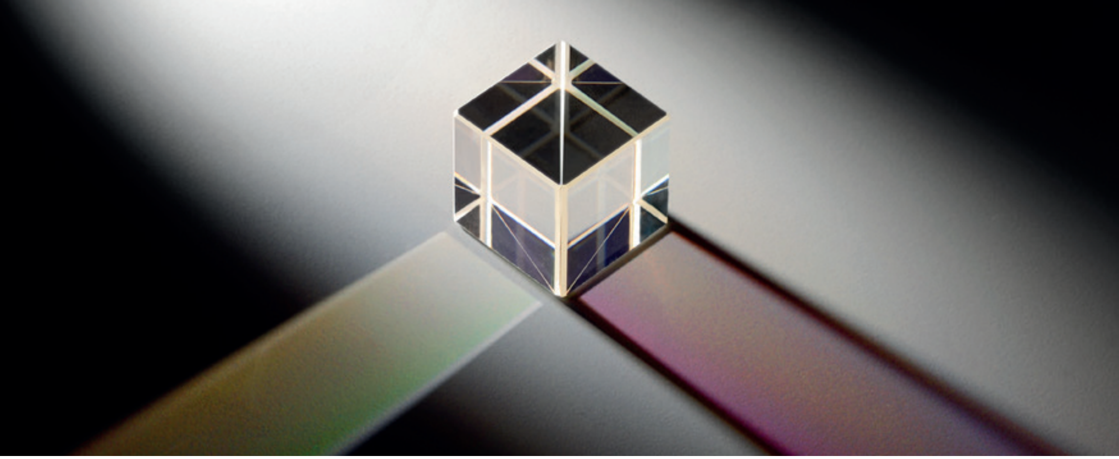
Interlayer-free bonding technologies adapted to glass and glass-ceramics

Fraunhofer IOF develops interlayer- and polymer-free bonding technologies for optical components that must withstand demanding operating conditions, such as high-power laser loads, harsh environments, or lithography and space applications. The processes are tailored to the specific materials and use case to deliver long-term stable, high-precision assemblies without adhesives.



Optical bonding technologies

Depending on the substrate and performance requirements, plasma-activated direct bonding or silicate bonding is used to realize monolithic, highly transparent components with mechanical strength of up to 80 % of the bulk material. Plasma-activated bonding creates covalent Si–O–Si bonds between the joining partners, enabling UV-transparent interfaces and high bonding strengths for a wide range of optical glasses, including lead-containing types such as SF11. Silicate bonding provides a solid, transparent joint that can compensate flatness errors of a few micrometers and is therefore well suited for curved surfaces and achromatic assemblies.

Typical demonstrators include high-power resistant beam splitter cubes, broadband polarizers with high contrast, GRISM elements, and achromatic optics made from combinations such as N-BK7 / N-SF6 and fused silica..

- Full transparency (bonding area is "invisible”)
- No uncontrolled creep/drift under mechanical load
- No outgassing at elevated temperatures
- No stress from thermal mismatch (for identical materials)
- Assembly of individual parts “accurate to gage blocks“

Top: Beam splitter cube with dielectric coating.

Left: Interlayer-free bonded prism-grating-prism.

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Optical coatings and surface functionalization

Turn demanding space optics into mission-ready hardware: Fraunhofer IOF develops and qualifies optical coatings and functional surfaces that keep their performance under launch loads, thermal cycling, and years in orbit. With more than 20 years of experience in coatings for space, astronomy, and high-end research, Fraunhofer IOF translates the optical requirements of costumers into robust, durable coating solutions.

Using advanced physical vapor deposition (PVD) techniques such as magnetron sputtering, Fraunhofer IOF deposits metal and metal-dielectric coatings that cover the full spectral range from the extreme ultraviolet (EUV, XUV) to the infrared (IR). Our portfolio includes EUV and XUV multilayer mirrors; aluminum- and fluoride-based coatings for UV and deep UV (DUV); highly reflective silver and gold mirrors for the visible and IR; broadband antireflection coatings; and ultra-black structured coatings for stray-light suppression. Researchers at Fraunhofer IOF apply these functional coatings to precision optics, freeform and lightweight mirrors, and complex optical components – from single prototypes to small series – for apertures up to one meter. Fraunhofer IOF supports customers along the entire value chain, from coating design tailored to the requirements of space missions through to full space qualification.

Our offer

- High reflective coatings from EUV to IR (Al-, Ag- or Au-based)
- Antireflection coatings for broad bandwidth and large ranges of incidence angles
- Optical dense structured coatings or absorbing coatings
- Handling and coating of complex optical components
- Realization of test programs for coating qualification

Top: Metal mirror coating using a sputtering system.

Left: LIDAR Dome with anti-reflective coating.

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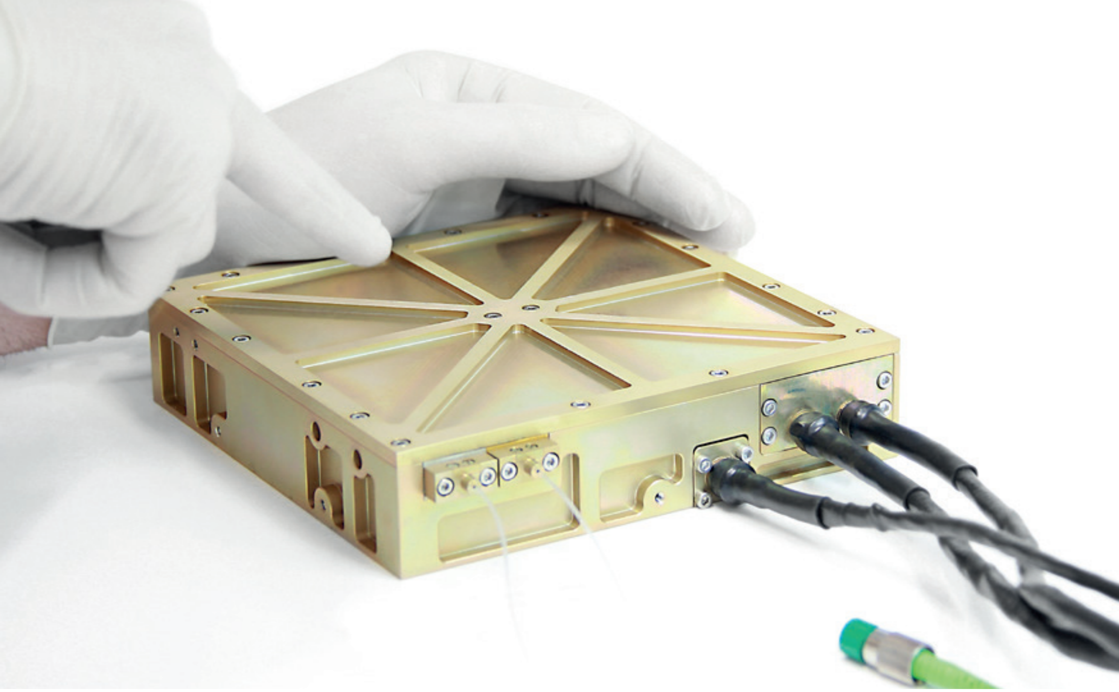

Fiber laser applications

Robust fiber lasers are a key enabling technology for next-generation space missions in ranging and detection, communication, and Earth observation. High efficiency, diffraction-limited beam quality, and inherent alignment stability make them ideal for operation under vacuum, radiation, vibration, and large temperature swings.

Many current concepts for spaceborne LIDAR (light detection and ranging) place demanding requirements on the laser source: high peak power and efficiency, excellent beam quality, and long-term reliability in harsh environments. Fiber lasers are therefore a prime candidate for such systems. Eye-safe pulsed fiber lasers at 1550 nm have been realized and demonstrated under realistic space conditions, for example as part of a LIDAR sensor used during ESA's ATV-5 rendezvous and docking maneuver with the ISS in 2014. With kilowatt-level peak power and high repetition rates, these systems enable

kilometer-range object detection with centimeter-scale resolution, relevant for rendez-vous sensors and for tracking hazardous space debris.

Building on this space heritage, Fraunhofer IOF supports customers in developing and qualifying fiber-laser-based sources and subsystems for demanding missions.

Discover the versatility of fiber lasers

- Laser development and qualification
- Assembling and joining technology
- Nonlinear optics
- Fiber design and fabrication
- Simulation and analysis

Top: LIDAR system in development.

Left: High-performance short-pulse fibre laser for LIDAR applications.

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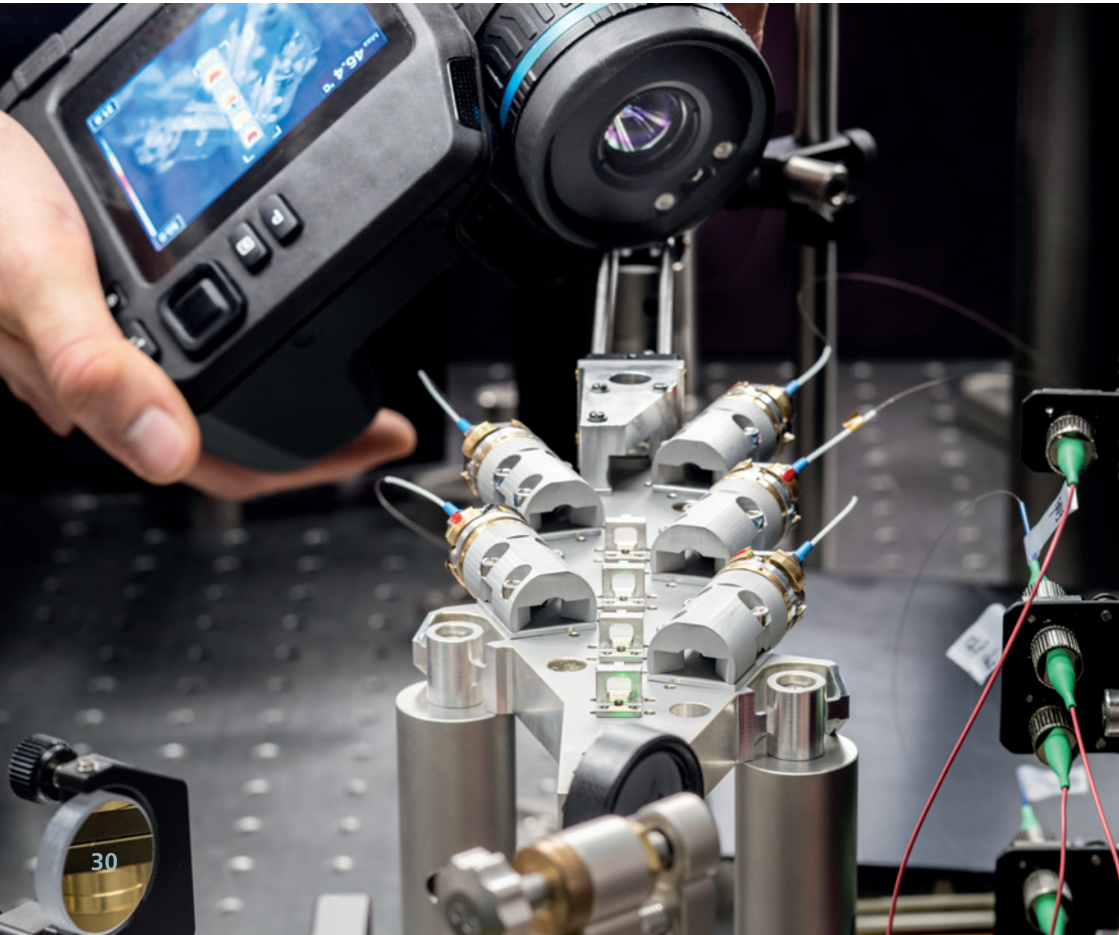
Satellite-based laser communication

Laser communication promises data rates in the gigabit to terabit range for satellite networks. Fraunhofer IOF develops components and systems such as transmit and receive telescopes for satellite-based laser communication.



Components and systems for space laser links must combine high optical power, excellent beam quality, precise pointing, and long-term stability in the harsh space environment. Building on its expertise in space optics and photonics, Fraunhofer IOF develops key building blocks for such optical links. Modular subsystem designs allow these technologies to be tailored to different mission scenarios: feeder links for high-throughput satellites, inter-satellite backbone connections, or space-to-ground links for data downlink and future quantum-ready networks.

What we offer

- Optical terminals for space links
- WDM high-capacity transmit modules
- Beam stabilization & pre-compensation
- Compact rugged opto-mechanical designs
- System studies & link analysis

Top: Space-qualified fiber-optical multiplexer.

Left: Wavelength multiplexer for high data rates.

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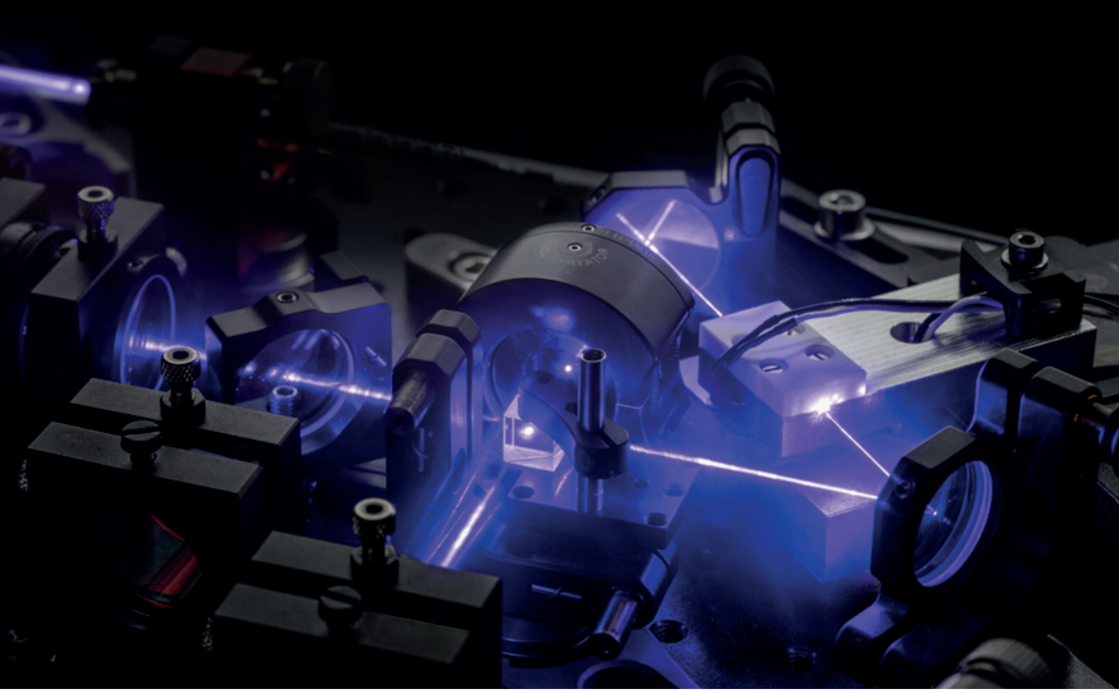
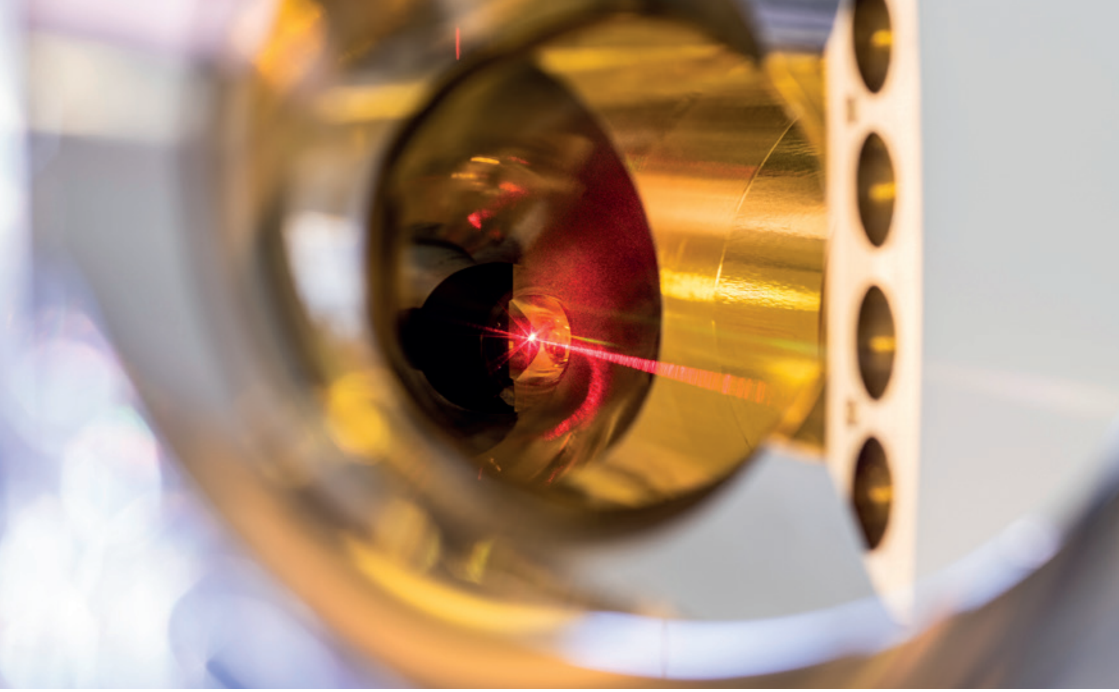


Optical quantum technologies for secure data transmission

Quantum communication adds a new security layer to future space and ground networks by enabling provably secure, tap-proof optical links. Satellite-based quantum key distribution (QKD) will play a key role in extending quantum-secured communication beyond the reach of terrestrial fiber networks.

Farunhofer IOF develops tailored photonic solutions for quantum communication and crytography in demanding environments – from space-capable high-brightness sources of entangled photons and quantum-ready transmitting/receiving telescopes to adaptive-optics-based modules that stabilize and clean up quantum signals on their way through the atmosphere. Our expertise covers the full chain from concept and optical design to prototypes and field demonstrations in collaboration with industry and space agencies.



Unlock incredible features

- Employing adaptive optics and quantum hardware for satellite-based quantum communication
- Exploiting high-dimensional photonic entanglement and hyperentanglement for distributed quantum information processing
- Engineering the spatial and spectral structure of biphotons
- High-dimensional quantum information processing in the spatial and temporal domains
- Developing technologies for ranging and remote sensing with non-classical states of light

Top left: Source of entangled photon pairs for QKD generation.

Top right: Telescope for free-space QKD exchange.

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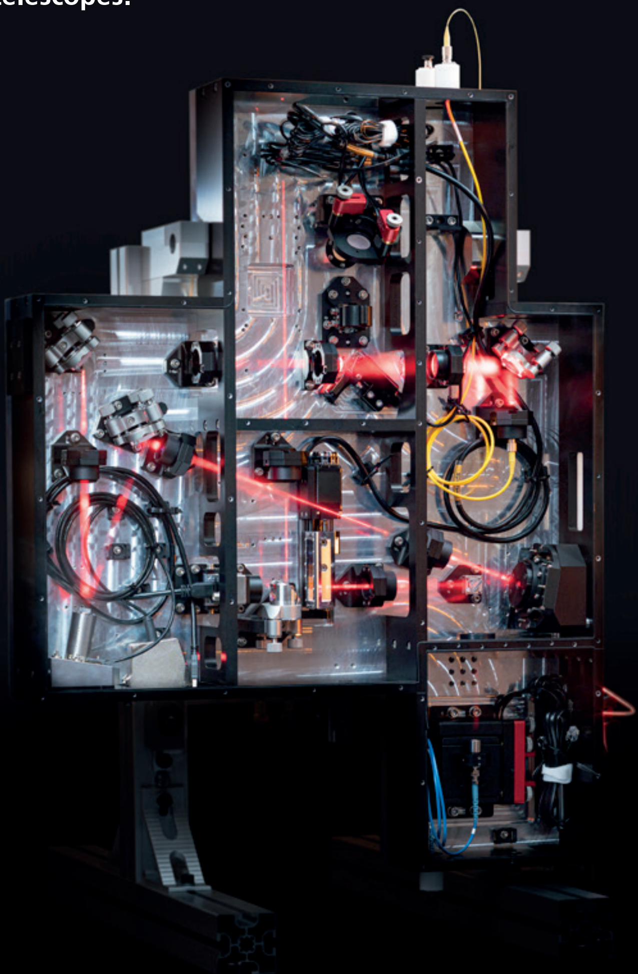
Active optics

Active and adaptive optical components and systems enable precise wavefront control in demanding laser and imaging applications. The thermal-piezoelectric unimorph deformable mirrors and active focus mirrors of Fraunhofer IOF compensate wavefront aberrations caused by thermal lensing, atmospheric turbulence, or quasi-static figure errors in space telescopes.



Core application fields include turbulence correction for free-space laser and quantum communication links (ground–space and space–space) as well as beam shaping and focus control in high-power laser systems. Fraunhofer IOF provides application-specific deformable mirrors and complete adaptive optics (AO) subsystems, including opto-mechanical design, control electronics, and software. Space-compatible packaging technologies and qualification procedures are available.

What we offer

- Thermal-piezoelectric unimorph DM wavefront compensation systems for high power optical systems (2kW/cm²) or for atmospheric turbulence
- Focus-only DM with 2-meter focal length
- Piezomotor-based lens adjustment systems

Top: Active metal mirrors for dynamic beam shaping.

Left: High-performance adaptive optics module for atmospheric turbulence correction.

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Optical Ground Station Jena (OGS)

The testbed for your upcoming quantum network solutions

The Optical Ground Station Jena provides a flexible testbed for free-space optical and quantum communication experiments. At its core is an 80 cm Cassegrain telescope that enables high-precision optical links to moving targets such as in-orbit satellites, aircraft, high-altitude platforms, or drones. The OGS is available to industrial partners, space agencies, and research institutions as a platform to validate components, subsystems, and complete terminals under realistic conditions. Typical use cases include classical and quantum key distribution (QKD) links, protocol and hardware testing, and end-to-end demonstrations for future quantum-secure networks.

- Interdisciplinary supporting team of physicists, optic designers, and engineers
- Free-space link infrastructure and intra-city link testbed
- Transportable QKD platforms for ad-hoc free-space links

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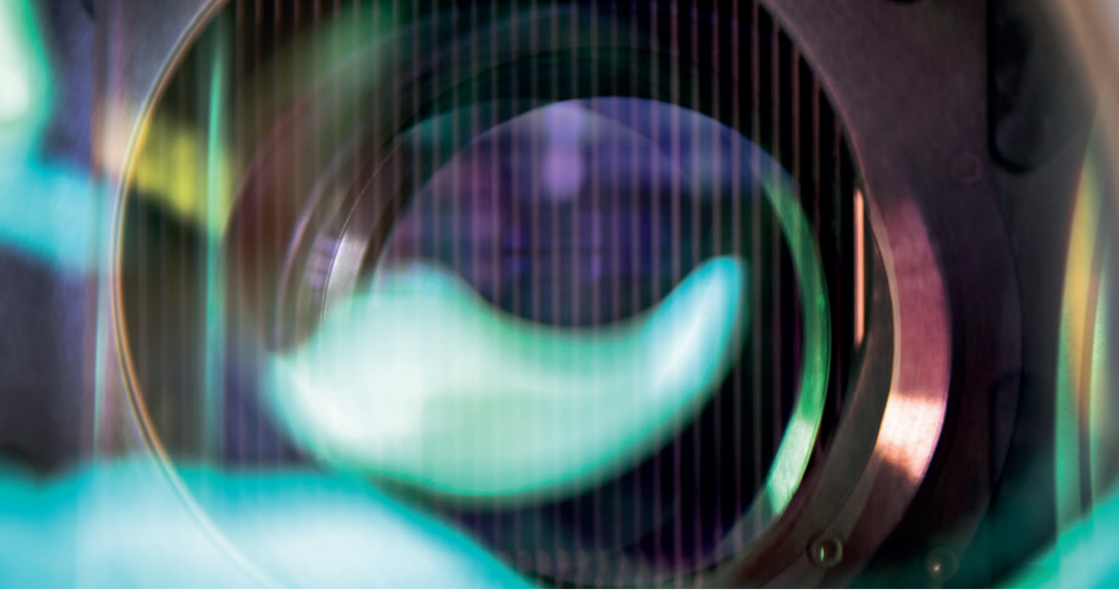

Direct beam profiling for large apertures

High-power, large-aperture laser beams are mission-critical in optical ground stations, free-space links, and advanced laser systems. Yet alignment drifts, thermal effects, and profile instabilities might erode link margin and power throughput. Our direct laser profiling solution provides a fast, non-intrusive way to see power, pointing, and beam shape and quality in real time—during commissioning, routine checks, and long-duration operation. Typical use cases include OGS uplink verification (LEO/GEO), terminal integration, QA of telescope-coupled beam paths, and field diagnostics where no dome or covering is available.

We engineered a field-ready device that brings lab-grade profiling to large apertures and high laser powers without the complexity typically required. A precision downsizing telescope scales wide beams to standard CCD and power sensors, while a calibrated partial-reflection path safely samples the signal—minimizing internal heat load and reducing cooling demands. An automatic alignment system with active actuators speeds setup and maintains precise pointing, and the software dashboard delivers live metrics and long-term trend analysis for both beam pointing and profile stability.

The platform is polarization-insensitive, currently designed for power levels up to 100 W and built around a modular optical design: 1064 nm today, easily adapted to 1550 nm and beyond. Robust sun and moisture protection make it truly field-capable. Higher power levels are possible.

What it provides

- Faster commissioning and alignment at OGS and terminal testbeds
- Reliable, repeatable QA of uplink beams and telescope-fed optics
- Early detection of mechanical drift and thermal effects via long-term monitoring
- Lower infrastructure effort thanks to reduced thermal load inside the device
- A clear path to closed-loop control, predictive maintenance, and scalable wavelength/aperture configurations

Top: Large aperture setup and it's installation on the OGS in Tenerife (© Fraunhofer IOF UAD-1064 | Tesat-Spacecom GmbH & Co. KG)

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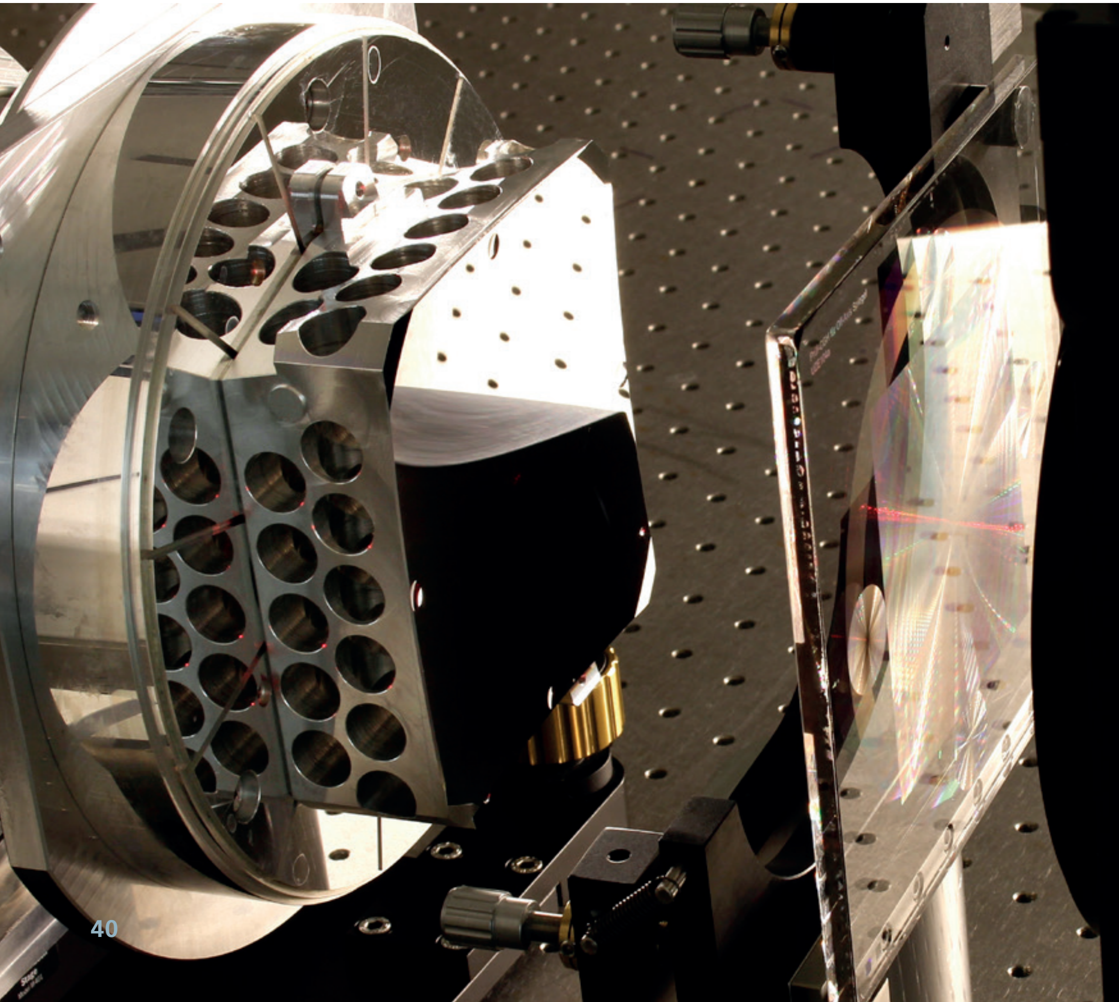
Metrology and stray light analysis

Accurate metrology and stray light analysis are key to ensuring the performance and reliability of optical systems in space and aviation. Advanced optical and tactile measurement techniques characterize individual optics and complete systems across a broad range of spatial frequencies with highest accuracy.



What we offer

Fraunhofer IOF combines interferometry, profilometry, and light-projection methods to determine the shape accuracy of high-precision optics, while AFM, white-light interferometry (WLI), laser scanning microscopy (LSM), and light-scattering techniques are used to measure surface roughness and scattering behavior down to the nanometer scale. The resulting data enable robust performance prediction and stray-light optimization for telescopes, spectrometers, and sensors in harsh environments.

- Shape characterization by high-precision profilometry, phase / wavelength shifting and highly dynamic interferometry with apertures up to 12'' plano
- Metrology of aspheres and freeforms with custom designed Computer Generated Holograms including alignment structures
- Data analysis and fusion using Power Spectral Density functions
- Evaluation of homogeneity, isotropy, cleanliness
- System testing and performance prediction based on light scattering models

Bottom: Radiometric Calibration Spectral Source (RCSS) for Webb measuring instruments .

Left: Computer-generated holograms for James Webb Space Telescope.

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Light scattering systems for high-performance optics

High-performance optics for space applications place extreme demands on surface quality and ultra-low optical losses. Even nanometre-scale roughness, sub-surface damage or tiny defects can cause light scattering, leading to loss of contrast or degraded system performance. Fraunhofer IOF supports the development and manufacturing of such optics with dedicated light scattering measurement campaigns and customised scattering systems – from early process development and in-line process control to qualification and acceptance testing.

Our experts combine angle-resolved and total light scattering measurements with complementary methods such as absorption, reflection/transmission, including cavity ringdown for reflectivities up to 99.999%, and surface topography analysis. This allows the full optical aperture of your components to be analysed: general surface roughness, inhomogeneities, contamination and local defects become visible in a single scatter map. Sub-surface damage can be detected non-destructively based on its specific scattering signature. Even large and strongly curved or freeform optics can be scanned efficiently to verify compliance with tight loss budgets.

Key features and services

- Tailored light scattering measurement campaigns for high-performance optics
- Angle-resolved and total scattering (BSDF) from EUV to IR
- Combined loss analysis: scattering, absorption and residual R/T down to the sub-ppm range
- Non-destructive detection of defects and sub-surface damage based on scattering signatures
- Design and realisation of customer-specific scattering systems

Top left: Light scattering measurement in a laboratory.

Top right: Light scattering measurement system MLS10.

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Optical 3D measurement systems

3D optical metrology enables fast and reliable acquisition of complex geometries for manufacturing, inspection, and maintenance in the aerospace sector – from aircraft engines to space hardware. Precise 3D data support condition monitoring, repair decisions, and documentation throughout the entire life cycle and form the basis for digital twins.

This includes

- Hand-held 3D sensors for condition monitoring of aerospace components
- Automated 3D-all-around measurement for component repair
- 3D data for digital twins
- High-speed 3D sensors for deformation analysis

Bottom: 3D scanning of an aircraft engine.

Left: Mobile 3D sensor mounted on a robotic platform.

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Let’s shape your next mission together – get in contact

Whether you are planning a new instrument, upgrading an existing payload, or looking for a long-term research and development partner: we invite you to get in touch with us.

For technology-specific questions, please contact the experts listed in each section of this brochure. They will be happy to discuss your requirements, possible technology options, and suitable development paths – from feasibility studies to qualified hardware.

If your inquiry spans several technology fields, or if you are unsure where your idea fits best, please contact **Stephanie Hesse-Ertelt**, coordinator of our space marketing strategy. She will route your request to the right specialists, coordinate cross-disciplinary in-house collaborations, and help assemble the optimal team for your mission.

We look forward to exploring ideas, developing solutions, and turning your optical concepts for aviation and space into reality.

Left: Prism-bonded optical grating.

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Editorial notes

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Photo acknowledgements


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