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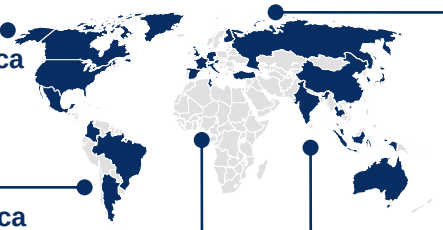
Ready for New Space

Novel Glass Solutions for Earth Observation

With a worldwide presence in 34 countries, the Astro & Space market is one of SCHOTT's core markets

Worldwide presence in 34 countries

43 production sites / 26 sales offices



North America
Canada
Mexico
USA

South America
Argentina
Brazil
Columbia

Middle East and North Africa
Dubai
Tunisia

Europe
Austria
Croatia
Czech Republic
Denmark
Finland
France
Germany
Great Britain
Hungary
Italy
Netherlands
Poland
Russian Fed.
Spain
Switzerland
Turkey

Asia and Oceania
China
India
Indonesia
Japan
Korea
Malaysia
Singapore
Taiwan
Thailand
Australia

Our goal is sustainable growth

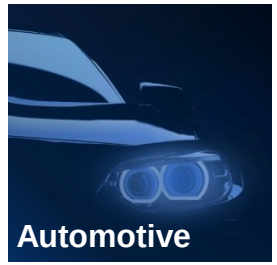
FY 2020/21

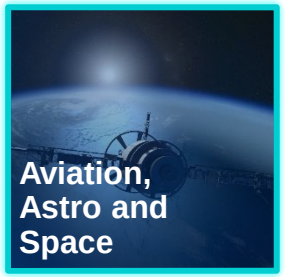
2.52 billion EUR
Global sales

17,300
Employees

Broad product portfolio for various markets

Astro and Space is a SCHOTT core market





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SCHOTT’s product offering for New Space

Contributes to diverse product solutions in various applications

Satellites (incl. Telescopes)

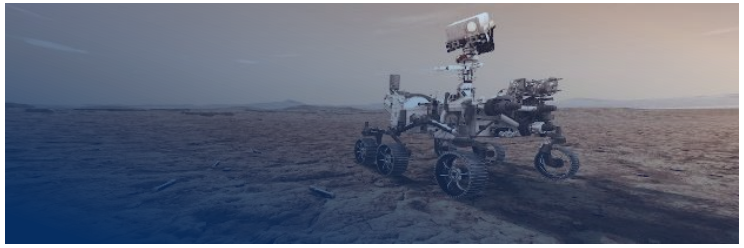
- **ZERODUR® mirror substrates** for telescopes, imaging and laser communication
- **Glass substrates** as thin protective cover for space photovoltaic applications
- **Glass substrates** for RF communication
- **FLEXINITY® connect** for advanced semiconductor packaging solutions
- **Fiber optic light guides** for satellite device alignment and calibration tasks
- **Radiation-hardened fiber optics** for image identification and detection
- **Hermetic micro-electronic packages** for reliable data communication
- **Glass cylinders** for hermetic sensor packages
- Radiation-resistant **optical glasses** for various applications
- **IRG chalcogenide glasses** for IR optical systems
- **SCHOTT active laser glass** for laser communication

(Ground) Stations

- **ZERODUR® mirror substrates** for laser communication
- **Glass substrates** for RF communication
- **Glass cylinders** for high frequency antennas (e.g., 5G)

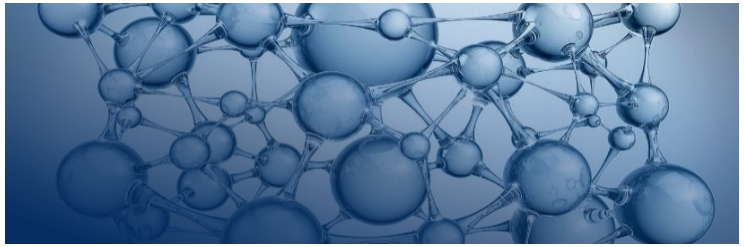
(Re-usable) Rockets

- **Flexible and rigid fiber optic bundles** for tank and propulsion monitoring
- **Porous glass** as thermal protective system/ heat shield for spaceships



Other Ventures

- **Glass powder** for creating oxygen via a SOEC for mars rover
- **Glass substrates** as protective glazing in space
- Laser-bonded **hermetic packages** for opto-electronic parts



Your Ideas

- **Customized solutions** to match your design specific requirements

RF – Radio Frequency; IRG – Infrared Glass; SOEC – Solid Oxide Electrolyzer Cell

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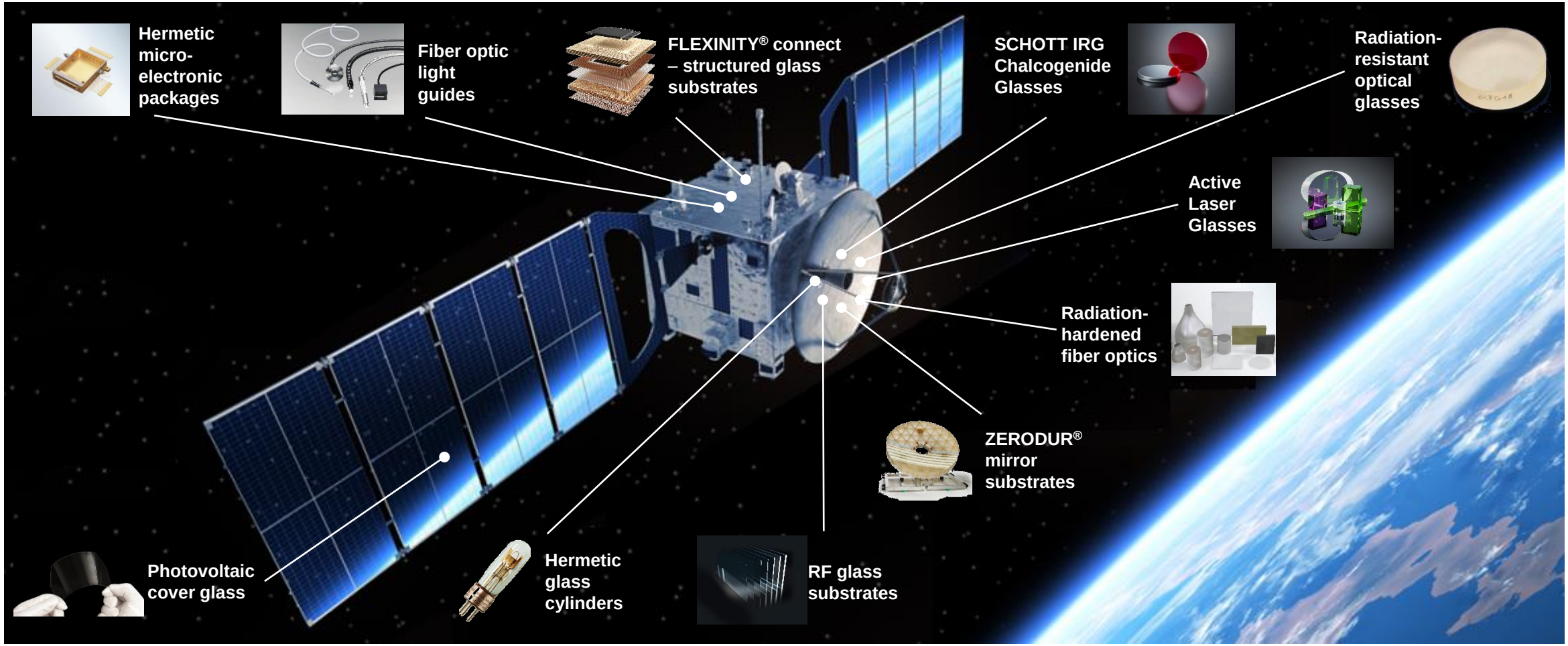
SCHOTT products enable a wide range of innovative solutions on board of satellites

SCHOTT's satellite product offering at a glance



IRG – Infrared glasses; RF – Radio Frequency

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ZERODUR® glass-ceramics mirror substrates

Light-weighted for space telescopes and earth observation

Near-zero thermal expansion

Highly homogeneous properties

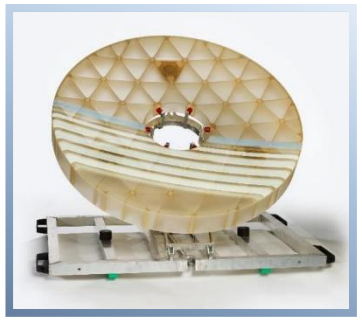
Usable under extreme conditions

CNC customized 3D shapes

ZERODUR® at a glance

- Monolithic material up to 4.25 m in diameter
- Near-zero coefficient of thermal expansion (CTE) over a wide temperature range
- Different CTE classes available with tolerances as tight as $CTE_{0°C, 50°C}$ [1)] of 0 ± 7 ppb/K
- ZERODUR® tailored with near-zero CTE for your application temperature profile
- Single-digit CTE homogeneity over the entire volume
- Extreme light-weighting up to ~90% possible

Space-ready light weighted mirror substrates

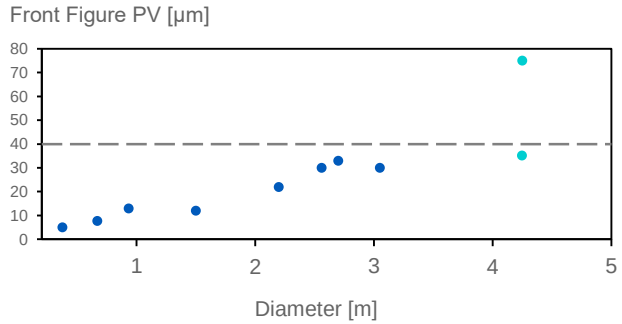


Diameter: [2)]	1200 mm
Edge Thickness:	125 mm
Rib thickness:	2 mm
Light weighting factor:	88 %
Face sheet thickness:	8 mm
Weight:	45 kg
First Eigenfrequency:	> 200 Hz
Front figure tolerance:	< 15 µm

Passed thermal test confirming NASA Technical Readiness Level (TRL) 6

Tight front figure tolerances for faster polishing

Front figure tolerance reveal P-V values below 40 µm for blanks up to 3050 mm in diameter. For larger blanks similar results are expected (light blue).



1) $CTE_{0°C, 50°C}$ average value measured at 0°C and 50°C
2) Smaller dimensions available for laser communication substrates

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SCHOTT’s radiation-resistant optical glasses

Proven to have a superior performance even after decades in Space

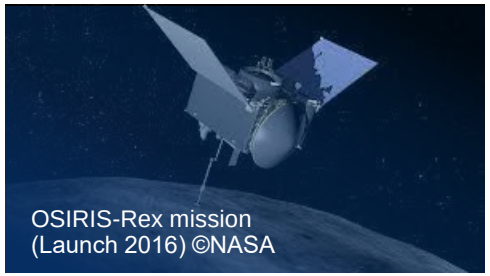
Solid portfolio of optical glasses [1)]

Excellent stability vs. ionizing radiation

Large pool of data & statistics

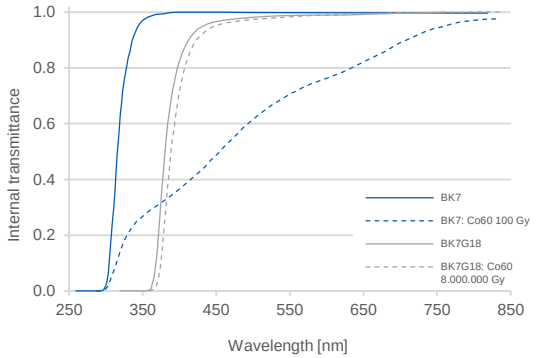
Outstanding experience


“Jade-Rabbit” moon rover (Launch 2013) ©CASC


OSIRIS-Rex mission (Launch 2016) ©NASA


Juno mission (Launch 2011) ©NASA


VENUS Express (Launch 2005) ©ESA



Radiation resistant glasses show high transmission even after a radiation dosage of several millions Gray.

BK7G18 is more yellowish compared to SCHOTT N-BK7® due to 1.8% Ce donation.

1) BK7G18, LF5G19, LAK9G15, F2G12, K5G20 & SF6G05 etc. as well as in variations as core glass for radiation hardened fiber optical components

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SCHOT IRG [1] Chalcogenide Glasses

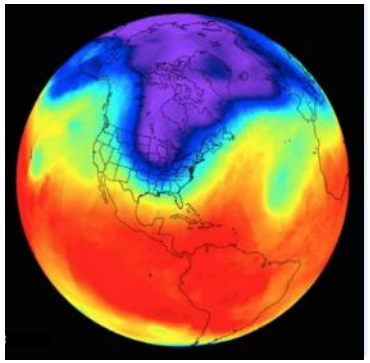
SCHOTT IRG glasses enable increased system level performance for IR sensors

- **High transmission**
- **Low dn/dt** [2]
- **No constraints in operation temperature**
- **Lighter than traditional IR materials** [3]
- **Radiation resistant**

SCHOTT's IRG glasses 22, 24, 25, 26 and 27

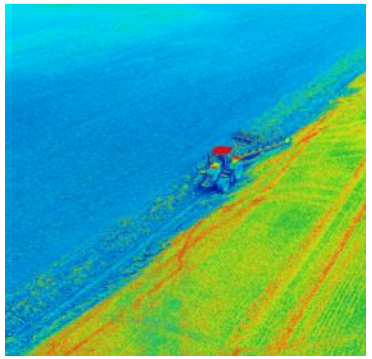
Range of Application

Thermography (temperature monitoring)



© NASA/JPL-Caltech AIRS Project

Agriculture analytics (e.g. water management)



System Level Benefits

- SWaP-C [4] savings; Decreases optical element weight by up to 39% vs Germanium
- Low dn/dT [2]: 12 to 21x better than Germanium (@ 10 µm)
- Less athermalization needed, which simplifies IR lens system
- High transparency (in SWIR, MWIR and LWIR) [5]
- No constraints in temperature: > 85°C like Ge
- Increased optical lens design possibilities through portfolio of IRG materials and properties (e.g., refractive index and dn/dT [2])
- Compatible with all existing IR materials and system designs
- LEO [6] radiation resistant

1) IRG – Infrared Glass; 2) Change of Refractive Index with temperature; 3) E.g., Ge; 4) SWaP-C – Size, Weight, Power and Cost; 5) SWIR – Short Wavelength Infrared, MWIR – Medium Wavelength Infrared, LWIR – Long Wavelength Infrared; 6) LEO – Low Earth Orbit

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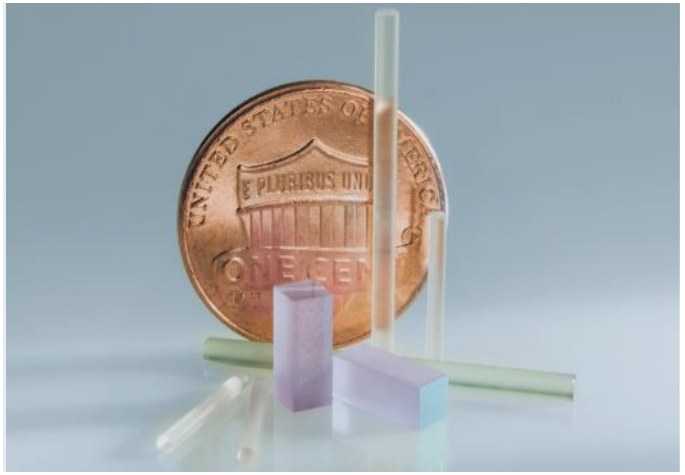
SCHOTT's active LG [1] 9xx series

SCHOTT active LG [1] enables efficient long distance laser based data transfer

- **Good athermal properties**
- **Highly homogeneous properties**
- **Tight material tolerances from melt to melt**
- **Very good size-to-performance ratio**

SCHOTT's Laser Glasses 910, 940, 950 and 960

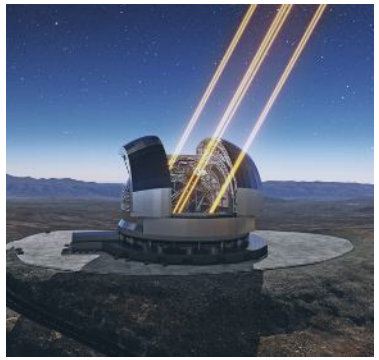


Range of Application

Satellite communication in the 1.5 µm wave band

Space-to-Space & Space-to-Air

Space-to-Ground



System Level Benefits

- Good athermal properties ensure stable operation
- High pump absorption in a short material length guarantees outstanding size-to-performance ratio
- Consistent beam quality and high homogeneity enable long distance data communication
- Glass types suitable for both diode and flash lamp pumping
- Very tight material properties and tolerances from melt to melt
- ITAR [2] free versions available

1) LG – Laser Glass; 2) ITAR – International Traffic in Arms Regulations

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