

Design and Performance of Raman Fiber Amplifier-based 589-nm Guide Star Lasers for ESO VLT and their suitability for future ELT AO Systems

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Outline

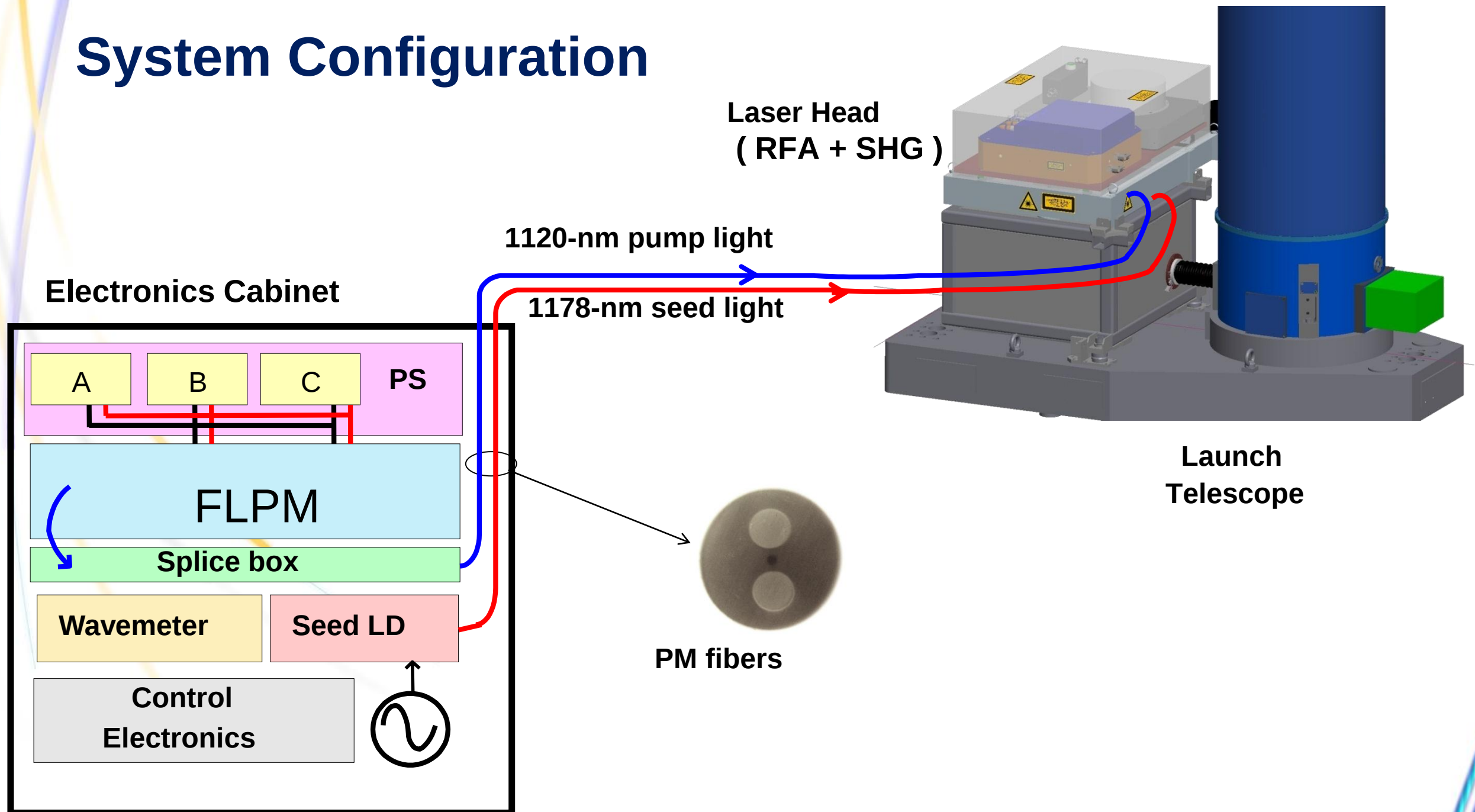
- Introduction
- RFA Based LGS Architecture
 - Overview
 - System Modules
 - Integration on Telescope
- Optical Performance
- Maintenance & Reliability
- Environmental Tests
- Conclusions

Raman Fiber Amplifier Based MOPA + SHG



- Developed by collaboration between Toptica AG (Germany) and MPB Communications Inc. (Canada)
- Based on ESO Patent WO 02/073754 A2
- Toptica, leader in precision wavelength stabilization, tuning and linewidth control and second harmonic generation. Established in 1998.
- MPBC, leader in fiber-optic communication, high-reliability fiber lasers and amplifiers and Raman technology. Incorporated in 1977.

RFA Based Laser Guide Star System Configuration



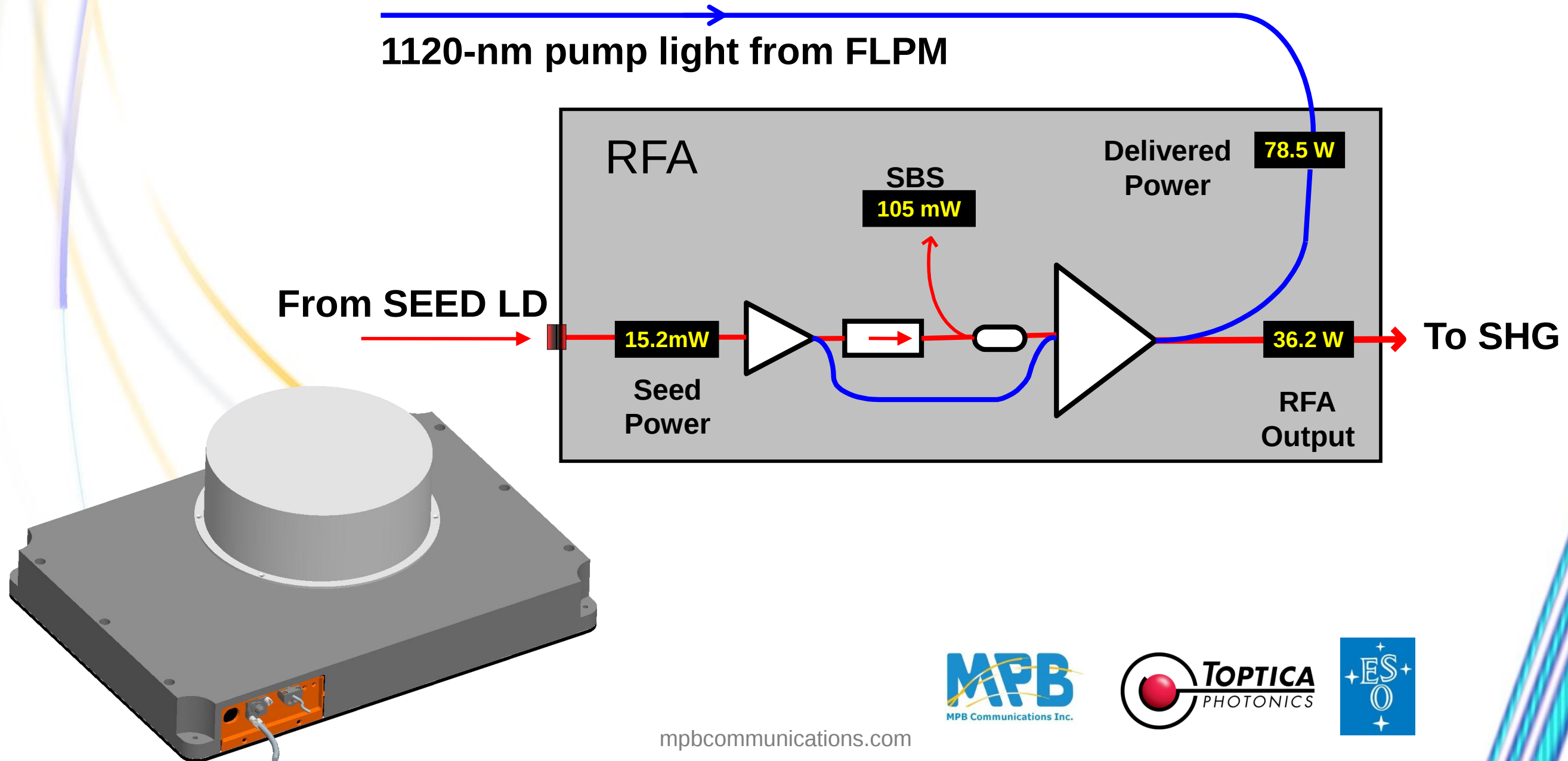
RFA Based Laser Guide Star

Key Advantages of Fiber-Optics Approach

- No bulk mirrors to align or clean - maintenance free
- Inherently immune to gravity vector changes
- Silica-based fibers - proven technology from telecom industry
- Large surface-to-volume ratio simplifies heat removal
- Closed, all-fiber optical path
- Single-mode PM fiber – inherently true diffraction-limited, linearly-polarized output
- Remote pumping capability allows mounting of compact Laser Head directly on launch telescope platform with connection to Electronics Cabinet via fiber-optic cable

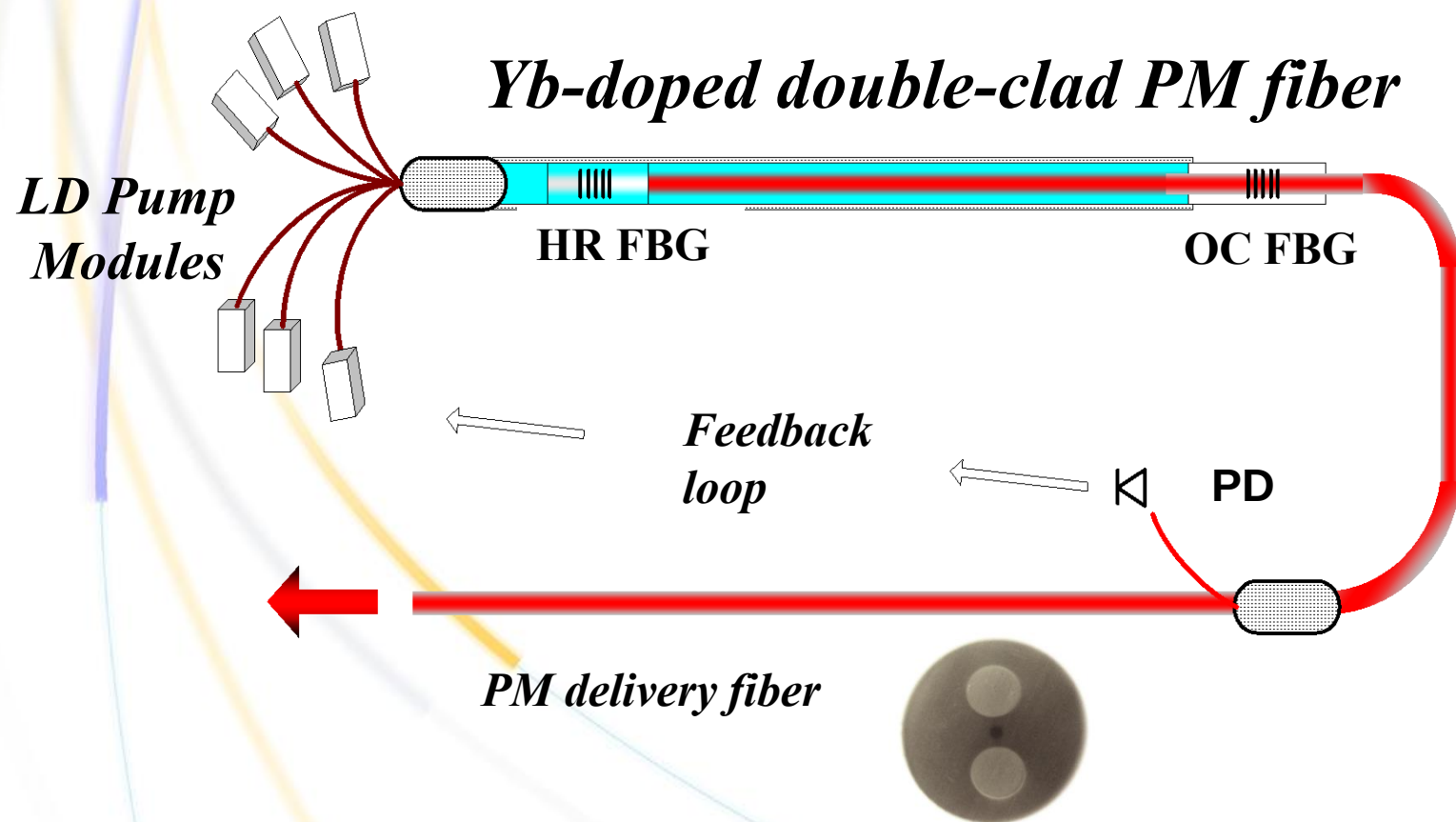
RFA Based Laser Guide Star

- Raman Fiber Amplifier Module -



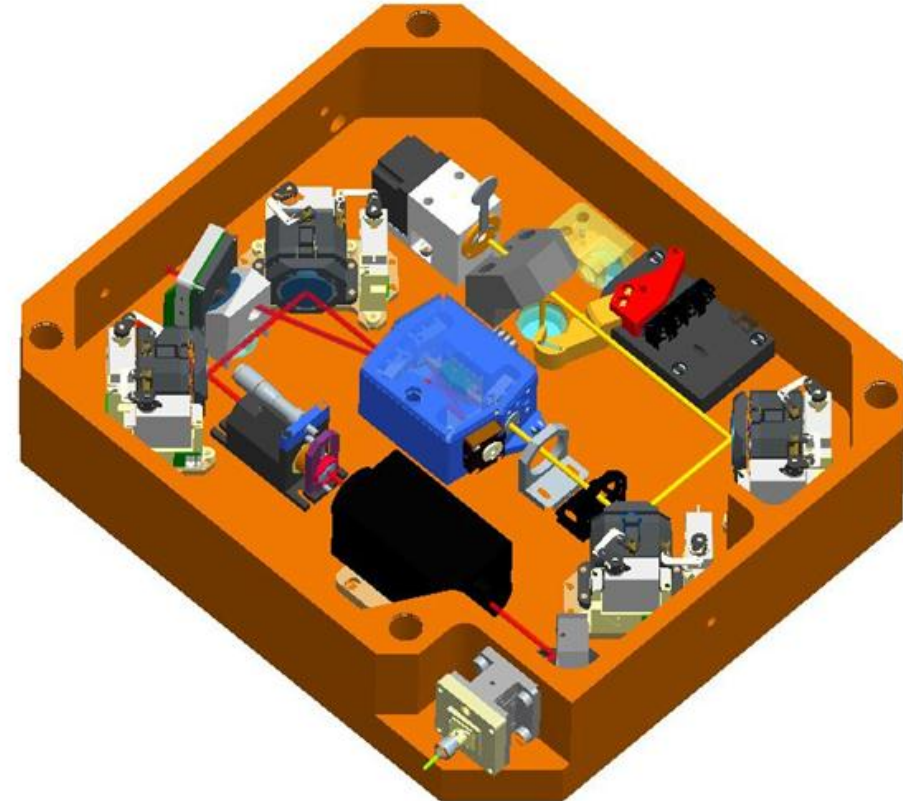
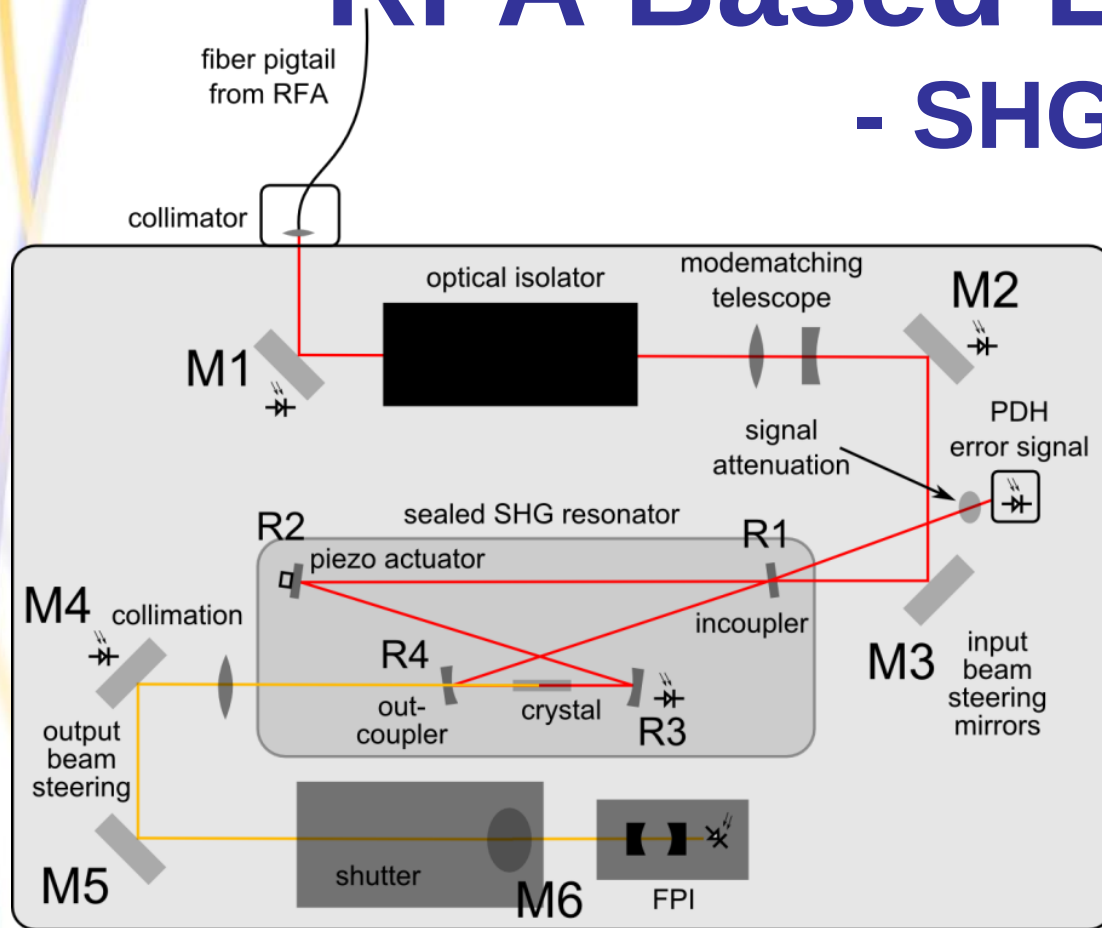
RFA Based Laser Guide Star

- Fiber Laser Pump Module -



- Up to 100 W at 1120 nm in PM single-mode fiber
- Multiple LD pump modules provide redundancy and simplify heat management
- Power consumption < 500 W

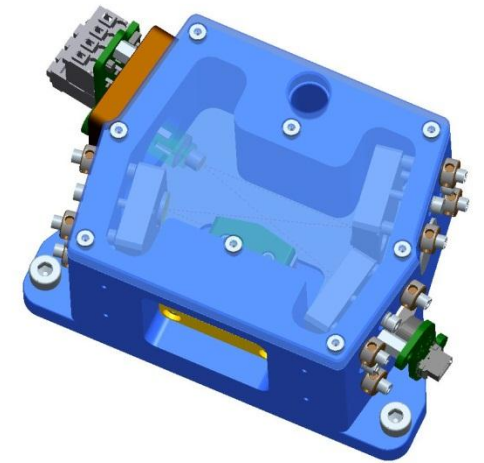
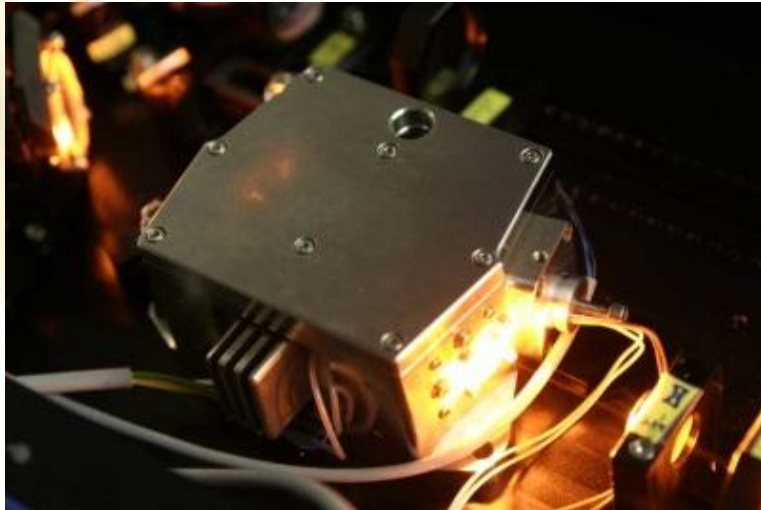
RFA Based Laser Guide Star - SHG Module -



Features:

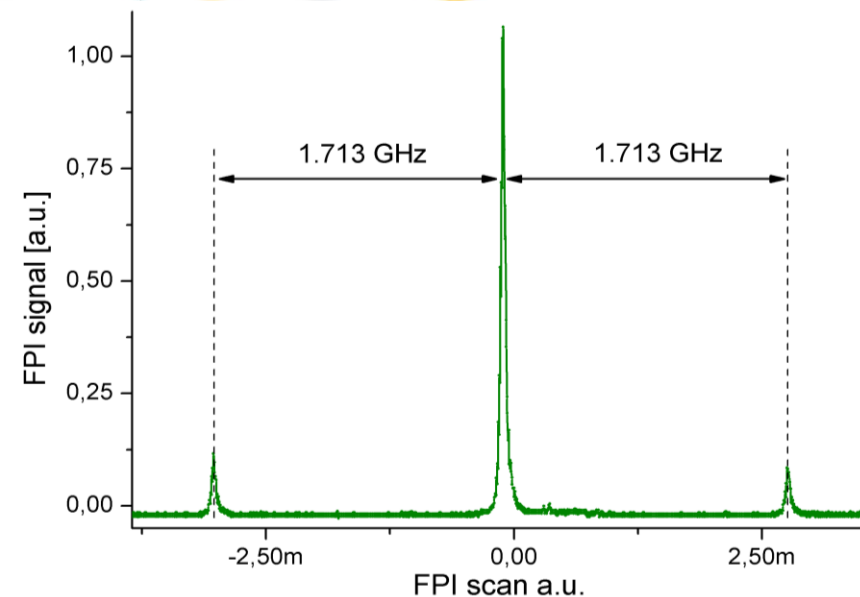
- Non-critically phase-matched LBO crystal
- Motorized mirrors for cavity coupling
- Control electronics integrated in top cover

RFA Based Laser Guide Star - SHG Resonator -



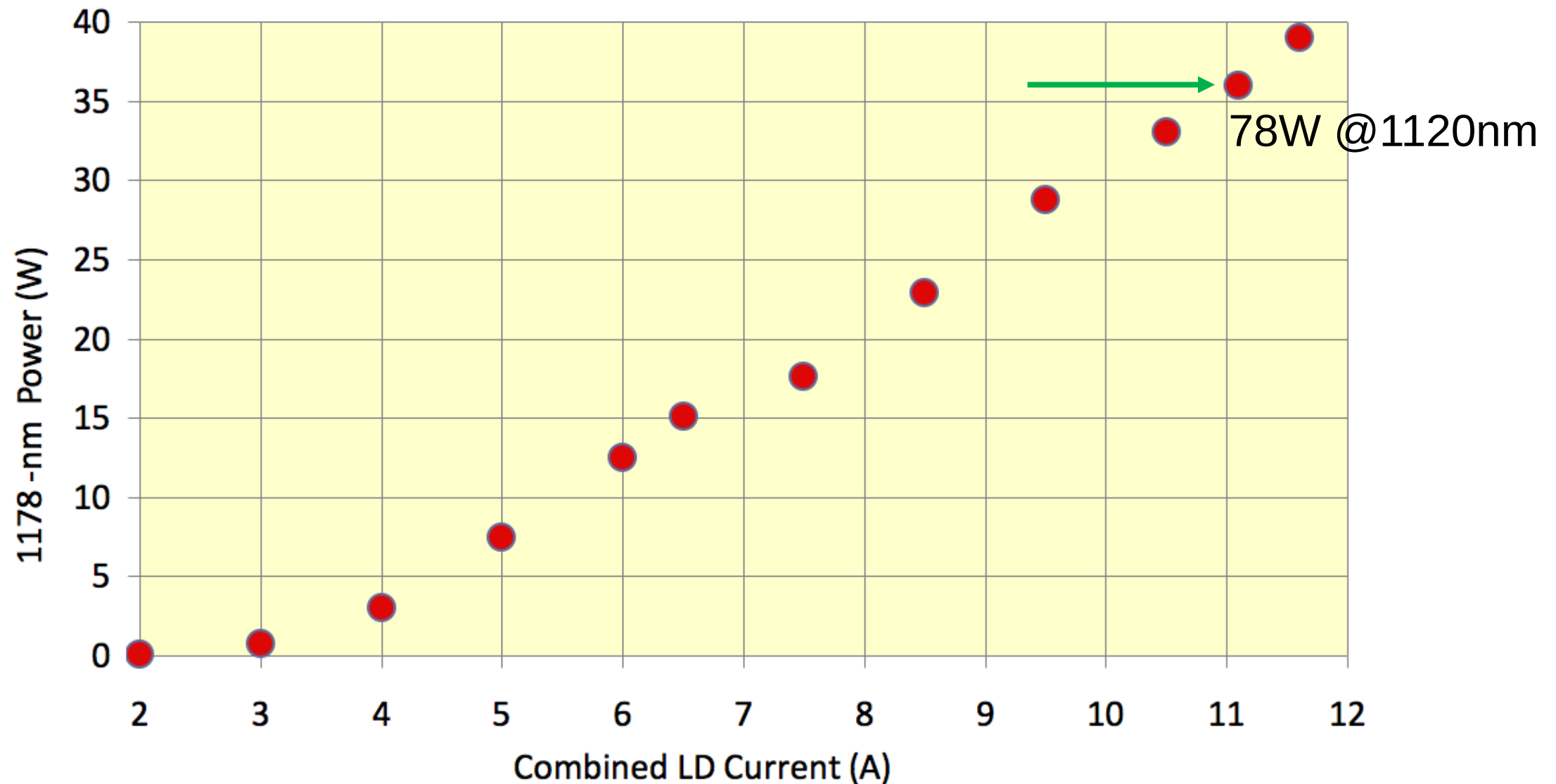
Features:

- Cavity length stabilization via Pound-Drever-Hall
- PDH modulation frequency 80 MHz
- Cavity acceptance bandwidth FWHM ≈ 50 MHz
- FSR of 1.713 GHz for simultaneous generation of D₂B re-pumper light
- Higher modulation orders strongly suppressed (<1%)



RFA Based Laser Guide Star - Optical Performance -

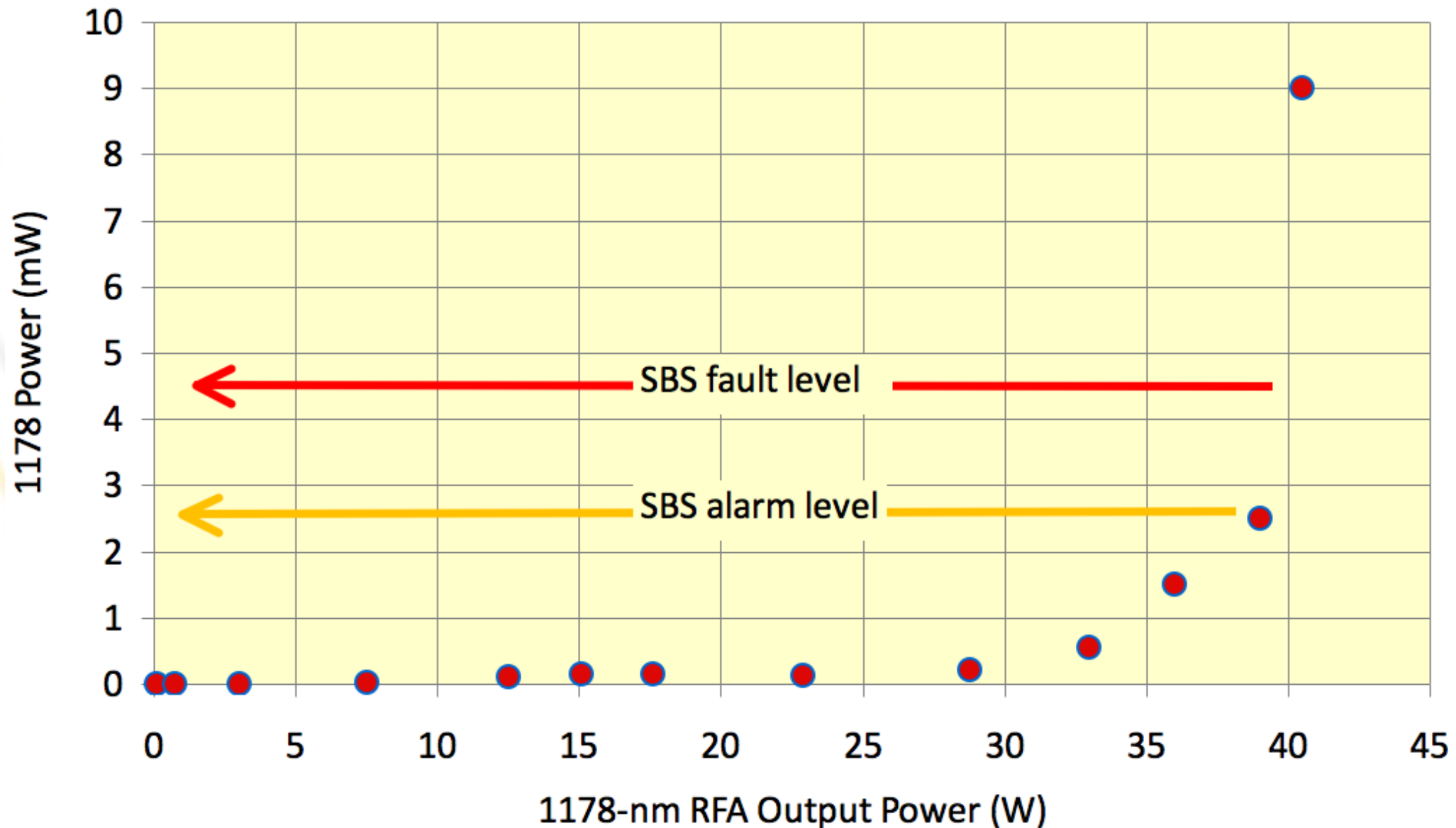
RFA output power vs FLPM combined LD current



RFA Based Laser Guide Star

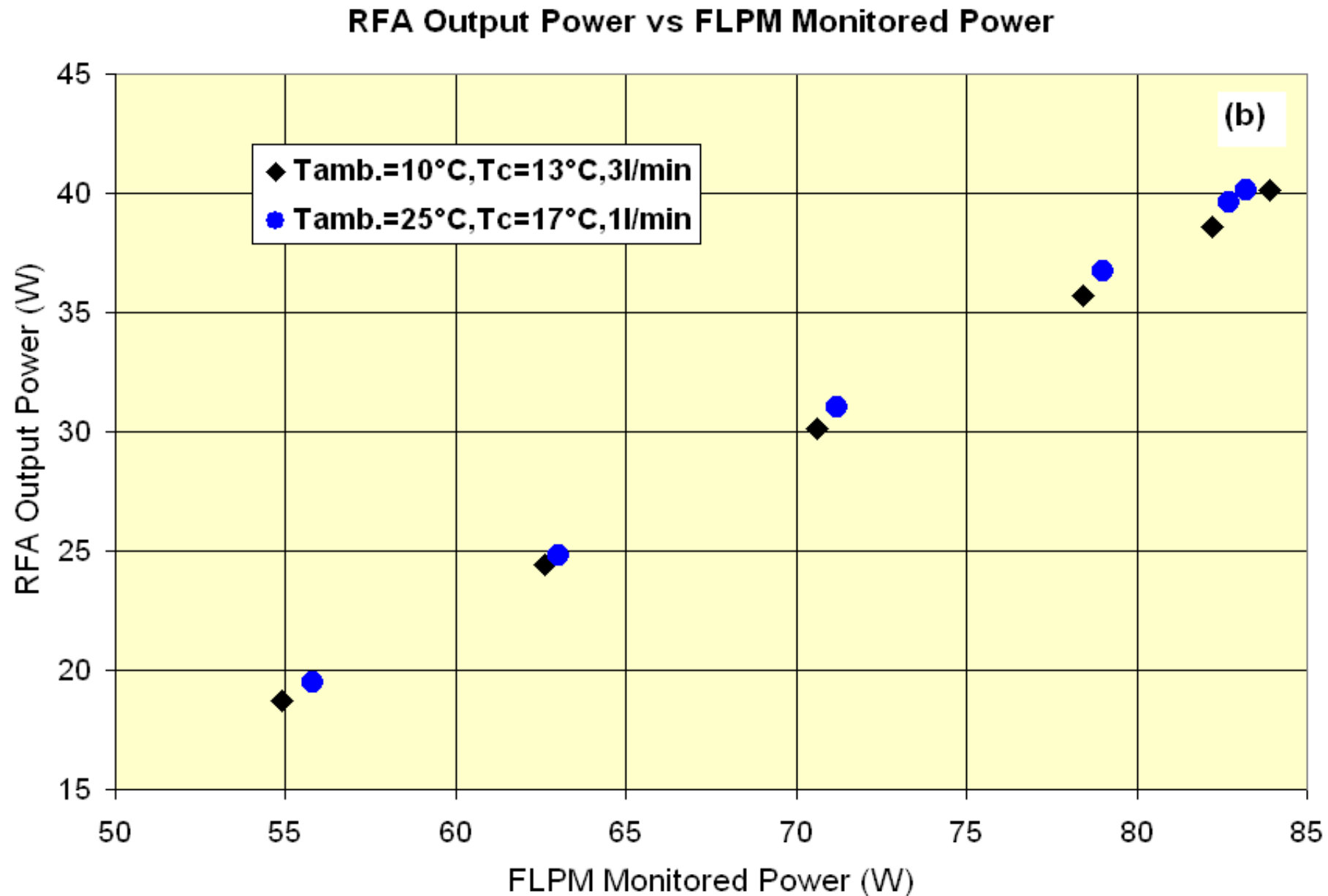
- Optical Performance -

Backward SBS power (at 1% tap) vs RFA output



RFA Based Laser Guide Star

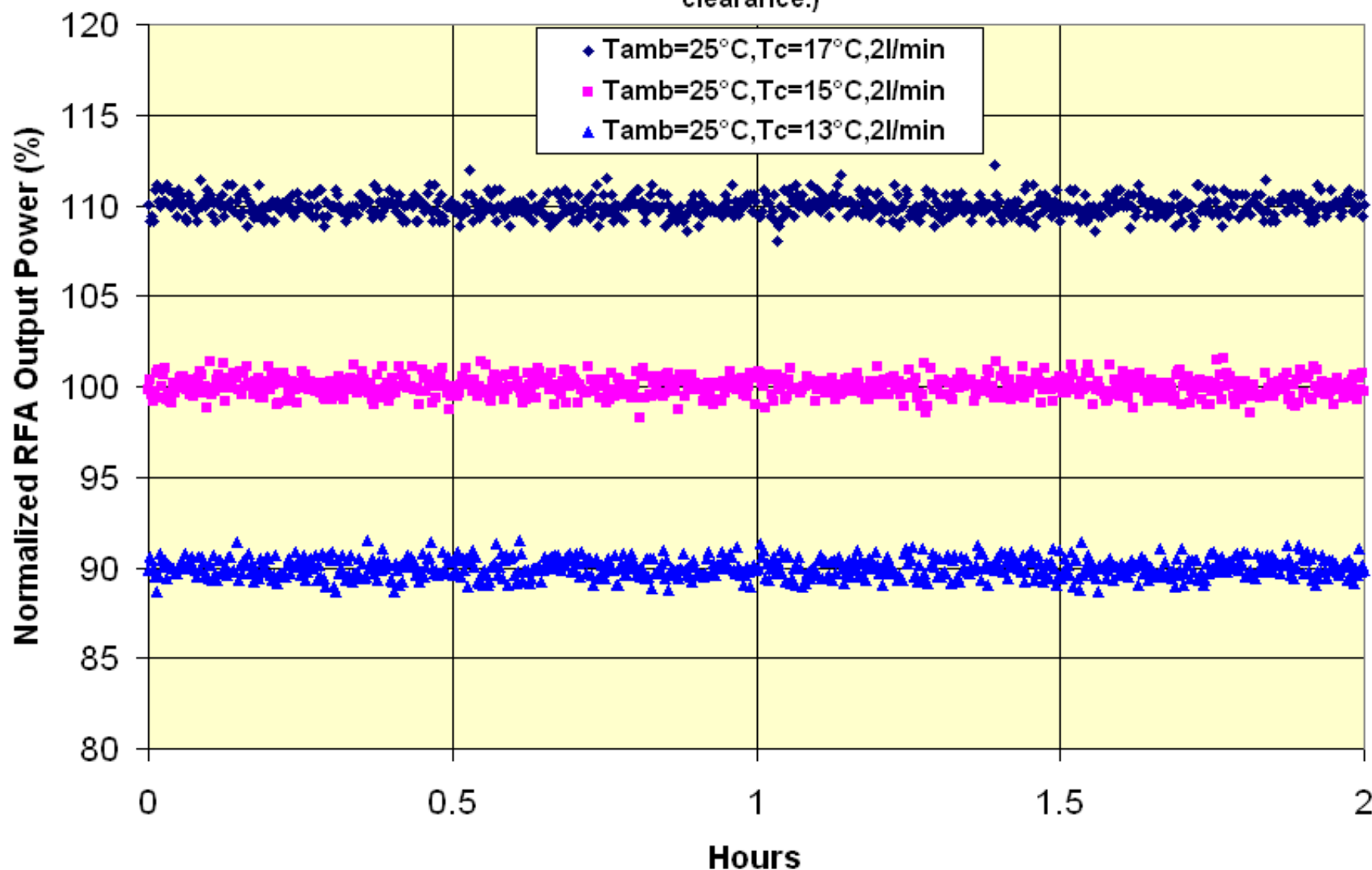
- sensitivity to coolant temperature and flow -



RFA Based Laser Guide Star - Optical Performance -

RFA Output Power Stability Under Different Conditions

(Stability curves at $T_c=13^\circ\text{C}$ and $T_c=17^\circ\text{C}$ have been shifted down or up by 10% for visual clearance.)

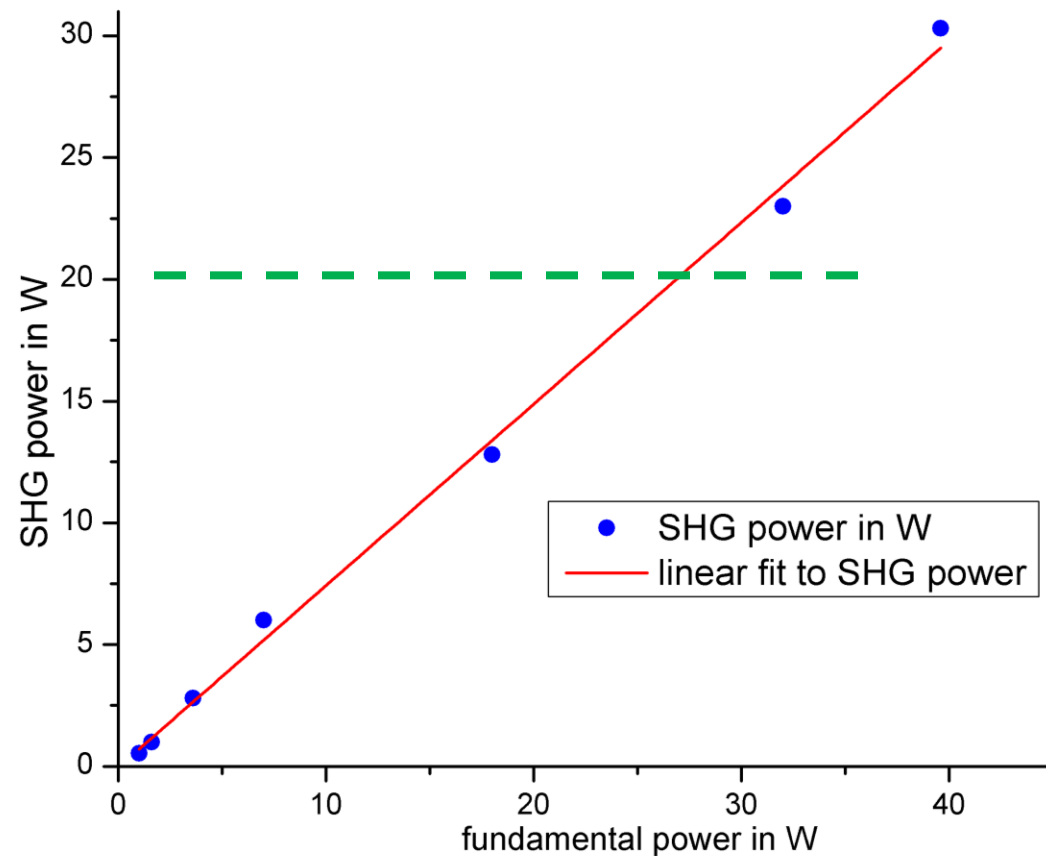


RFA Based Laser Guide Star

-Optical Performance at 589nm – full power

SHG Module Conversion Efficiency and Beam Quality

Frequency Doubling: Efficiency > 80%

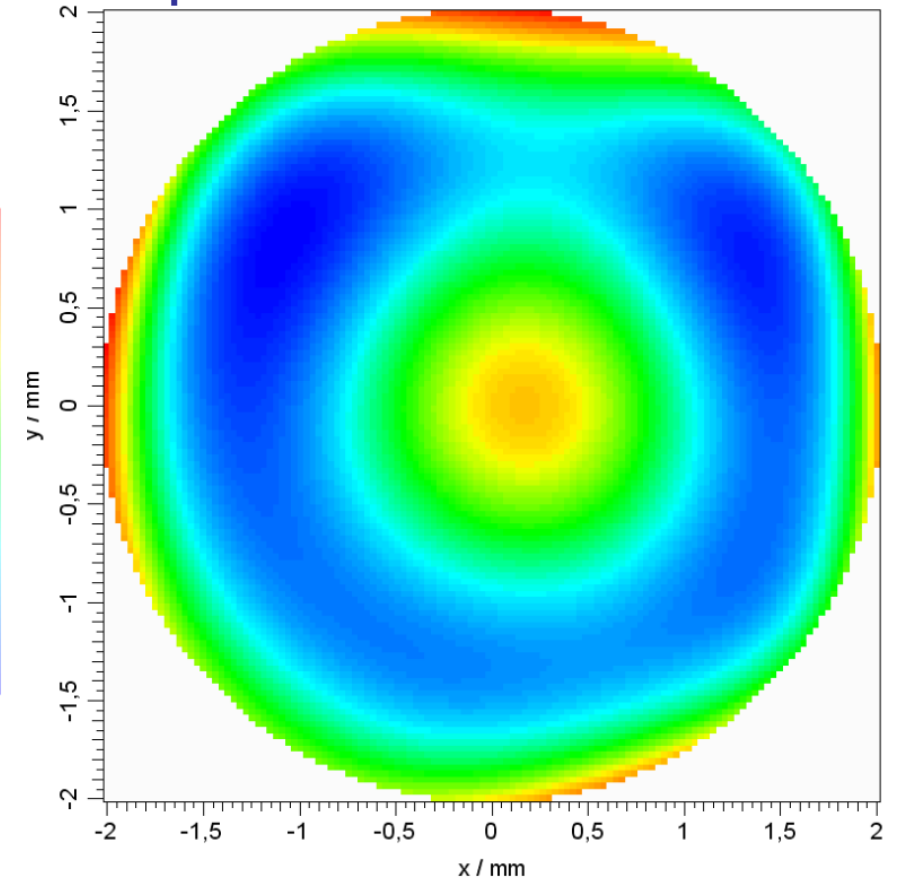


Specifications : WF error RMS < 70 nm

Experiment: WF error RMS < 20 nm

RMS 0,0315207
P-V 0,155661
Max 0,102074
Min -0,0535871

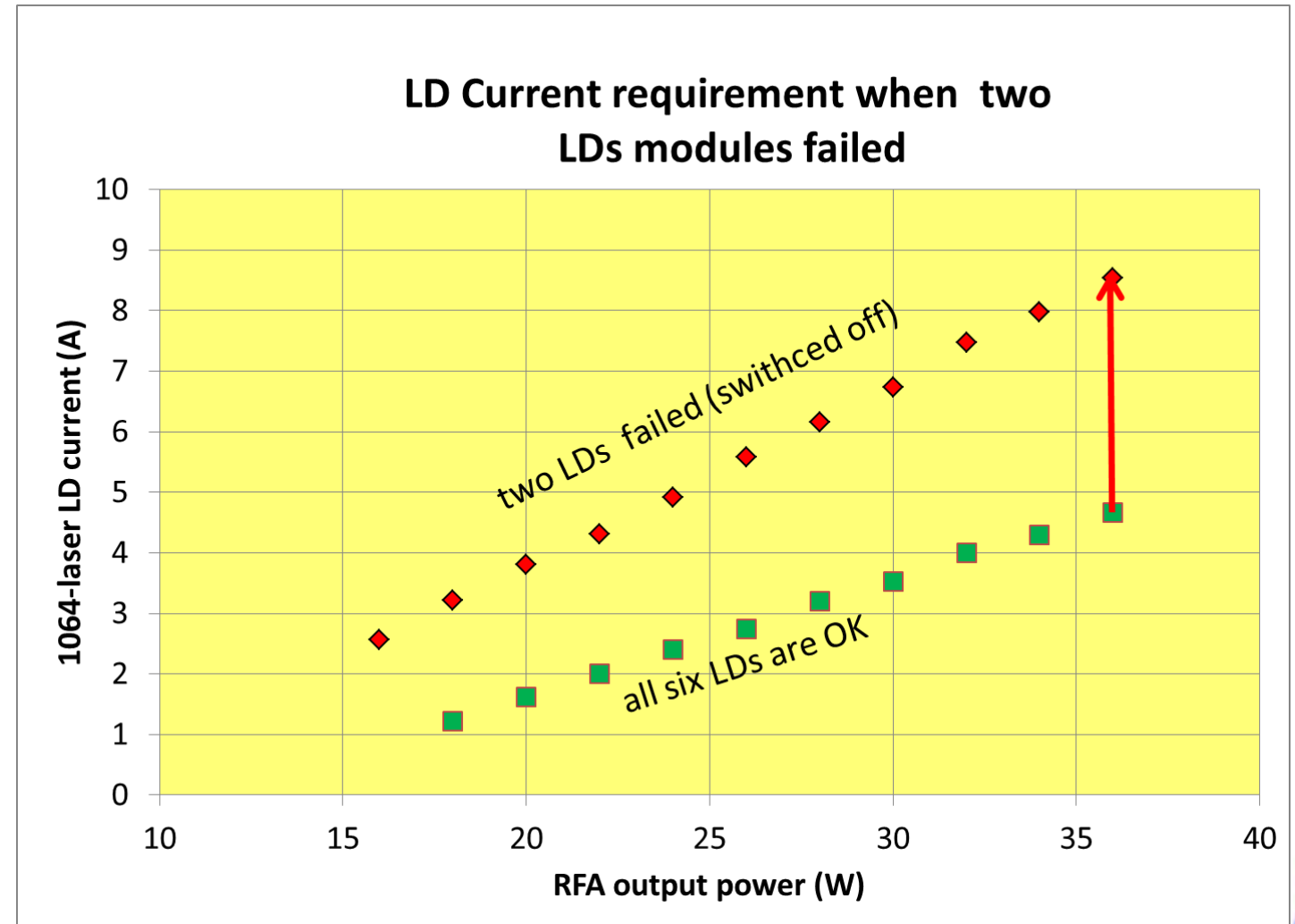
Korrigierte Wellenfront / $\lambda = 0,59 \mu\text{m}$



RFA Based Laser Guide Star - Maintenance & Reliability-

Pump Redundancy

- The failure of one LD or even two LDs still allows continued operation at nominal power of 36 W.
- In case of failure of 3 LDs, RFA can still provide a reduced output power of 20 W.

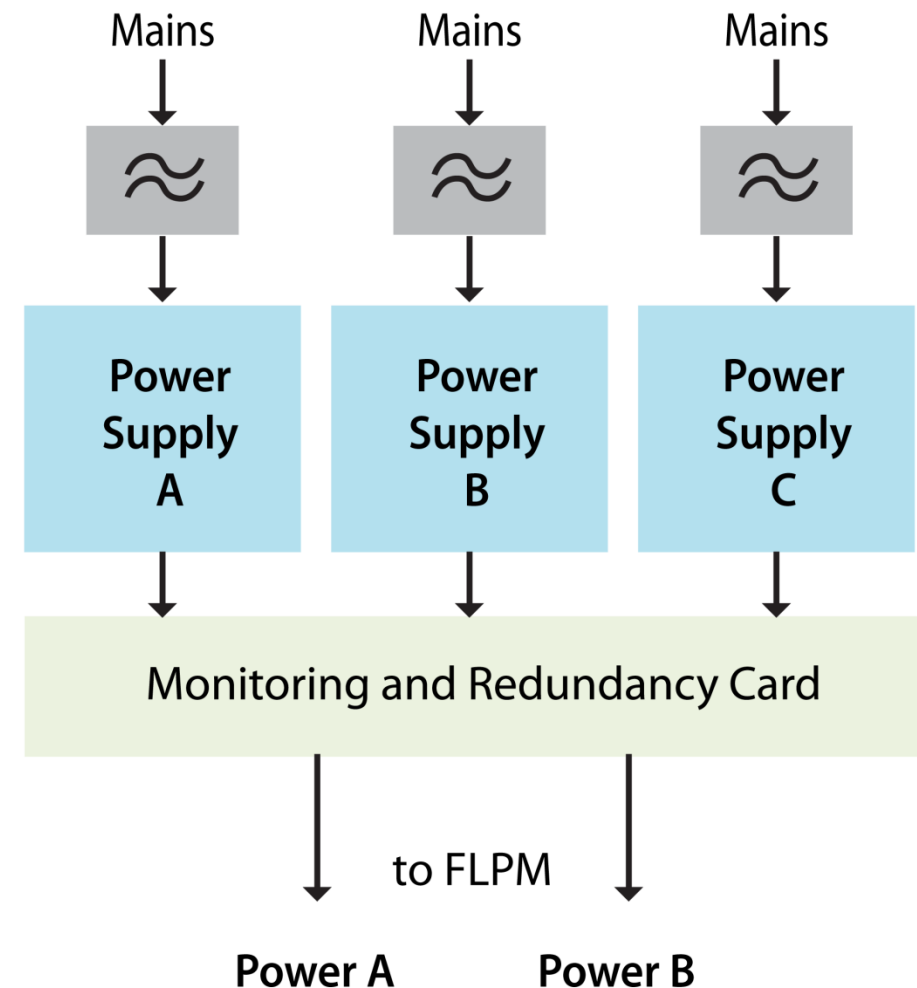


RFA Based Laser Guide Star

- Maintenance & Reliability -

Power Supply Redundancy

- 2 supplies active, 500 W each
- Redundant spare module
- Output Overvoltage / Undervoltage monitors switch the redundant module to take over for any failed main power supply
- Power Factor > 0.9
- Efficiency ~85%
- Wide input voltage range



RFA Based Laser Guide Star - Qualification Testing-

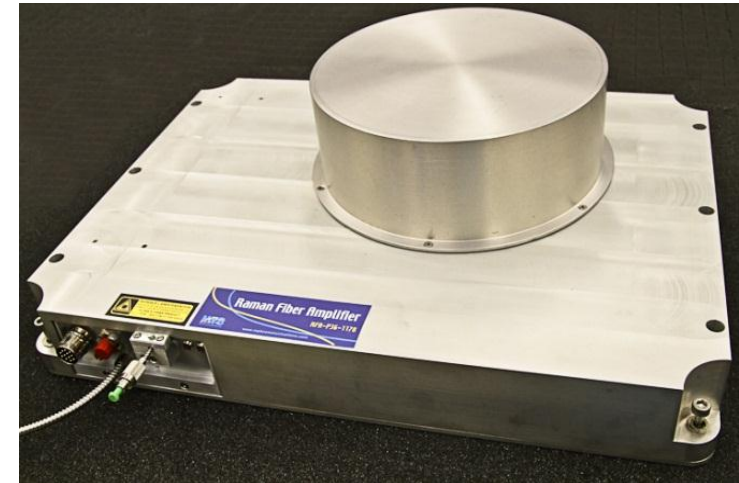
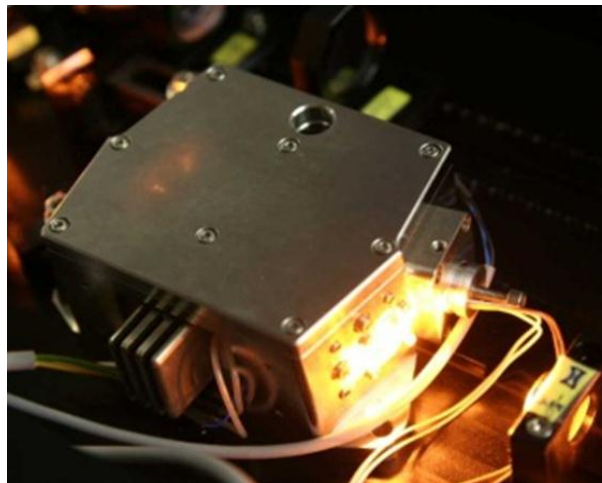
RFA Subsystem has successfully passed qualification tests to ensure compliance with ESO's demanding requirements for:

- Performance and functionality within operational and functional temperature ranges
- EMI/EMC Compliance
- Earthquake survival accelerations
- Transportation temperature/humidity

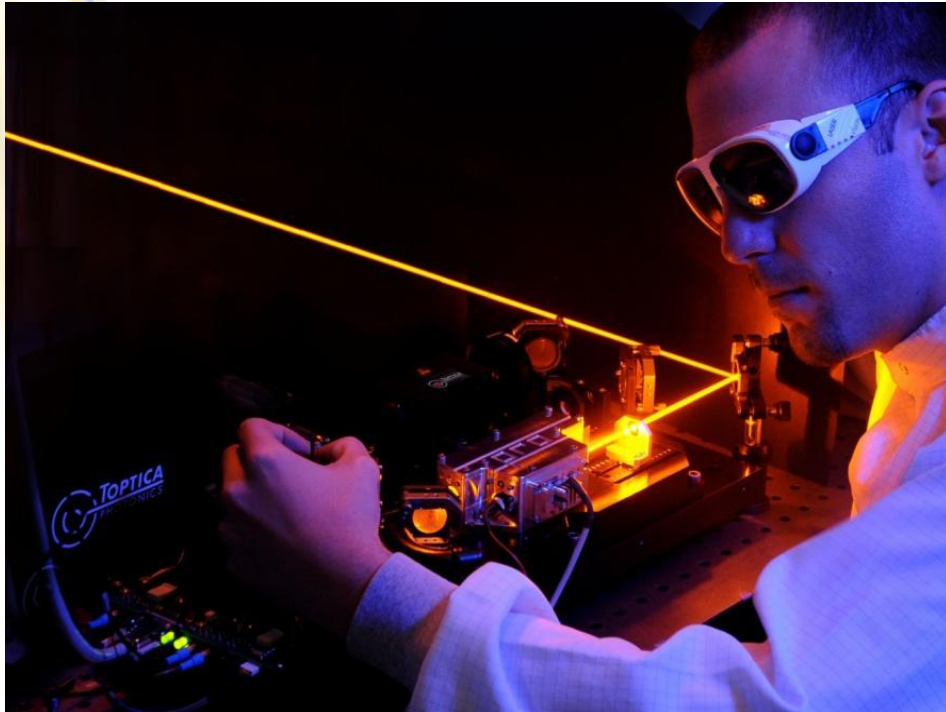
Next step, qualification testing of complete integrated LGS system

Conclusions

- We have developed high-power 589-nm lasers based on LD Seed, RFA and dual-band SHG modules for ESO VLT, pre-production laser unit scheduled for delivery to ESO in January 2012
- Extensive testing conducted to date confirms full compliance to ESO optical, electrical and environmental specifications



Conclusions



- Design is scalable to higher powers
- Remote pumping feature provides flexible installation options.
- Assured long-term support – laser developed and produced by well- established partners with long and successful track records.