Conceptual design of the optical subsystem of the proposed Lunar Laser Ranger

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Outline

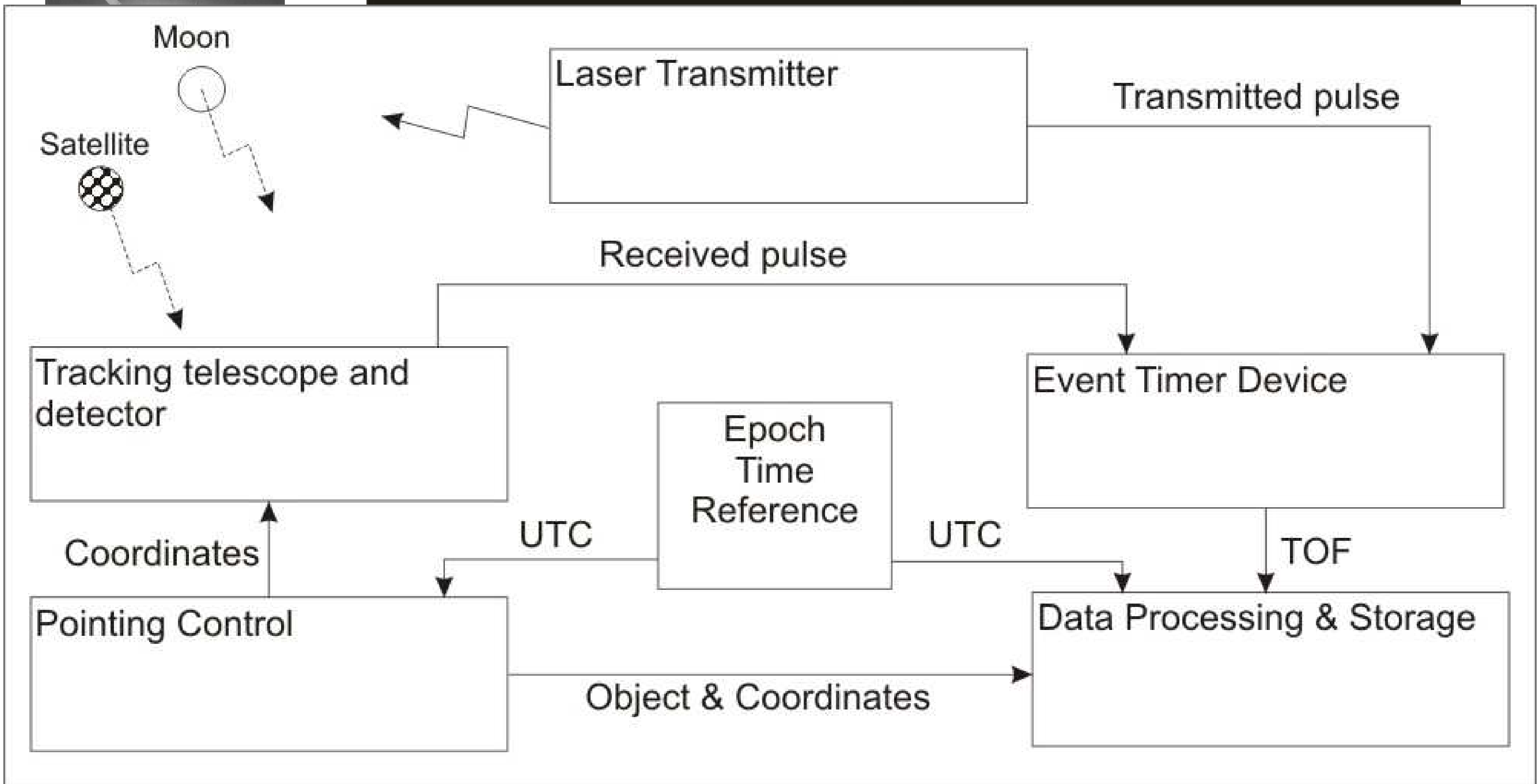
Conceptual optical subsystem design- Lunar Laser Ranger

- Background- Lunar Laser Ranging
- Conceptual Laser design, first results
- Conceptual design of optical subsystem

    1. Overview of dual telescope system
    2. Outgoing path design
    3. Receive path design
    4. Alignment

- Conclusion

GOAL: Lunar Laser Ranging



matter?”

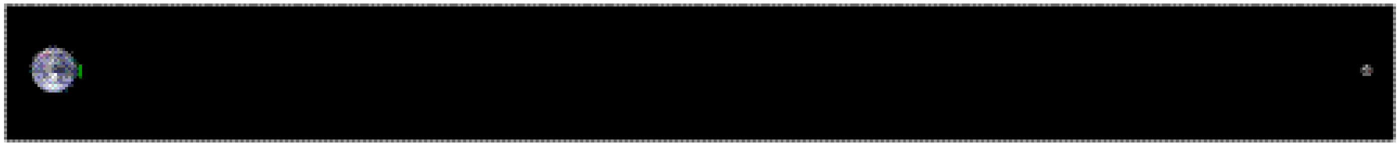
- To determine the time dependence of the universal gravitational constant G.

Laser Ranging: Link and Error budget

Link Budget from radar equation:

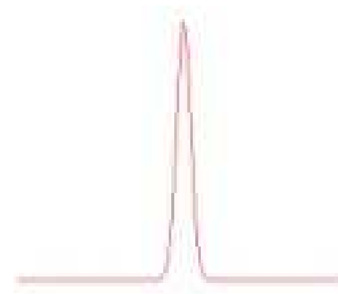
$$N_{pe} = \eta_q E_T \frac{\lambda}{hc} \eta_T G_T \sigma_{Sat} \left(\frac{1}{4\pi R^2}\right)^2 A_T \eta_R T_A^2 T_C^2$$

Transmit and receive-path efficiency



Source of error	**RMS Error (ps)**	**One-way error (mm)**
Leading edge variation of laser pulse	2 - 4	0.3 – 0.6
Laser pulse width	10 - 30	1.5 – 4.5
Jitter: Start detector	2 - 5	0.3 – 0.8
Jitter: Return detector	6 - 50	0.9 – 7.5
Time stability of clock	5 – 10	0.7 – 1.5
Calibration	2 - 4	0.3 – 0.6

Differences between SLR and LLR

	SLR	LLR
Measured Signal		
Transmit Signal		
Timing measurement	Interval	Event
Pulse Repetition Frequency	~ 5 Hz	~ 1 kHz

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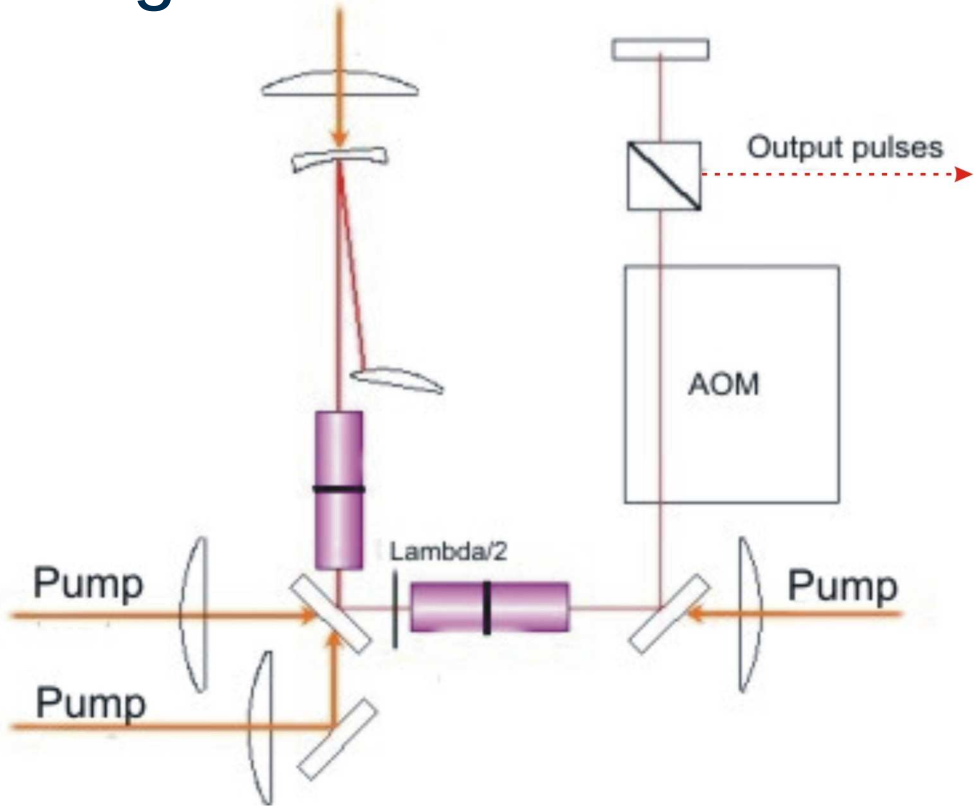
Conceptual Laser Design

For LLR laser we would like:

- ~ 500-540 nm wavelength
- < 50 ps pulse length (FWHM)
- M^2 close to 1
- 200 + mJ per pulse
- Pulse Repetition Rate: up to 2000 Hz



General Q-switched mode-locked parameters:

- Several microjoule per pulse
- Picosecond pulse length regime
- 100's of MHz pulse repetition frequency

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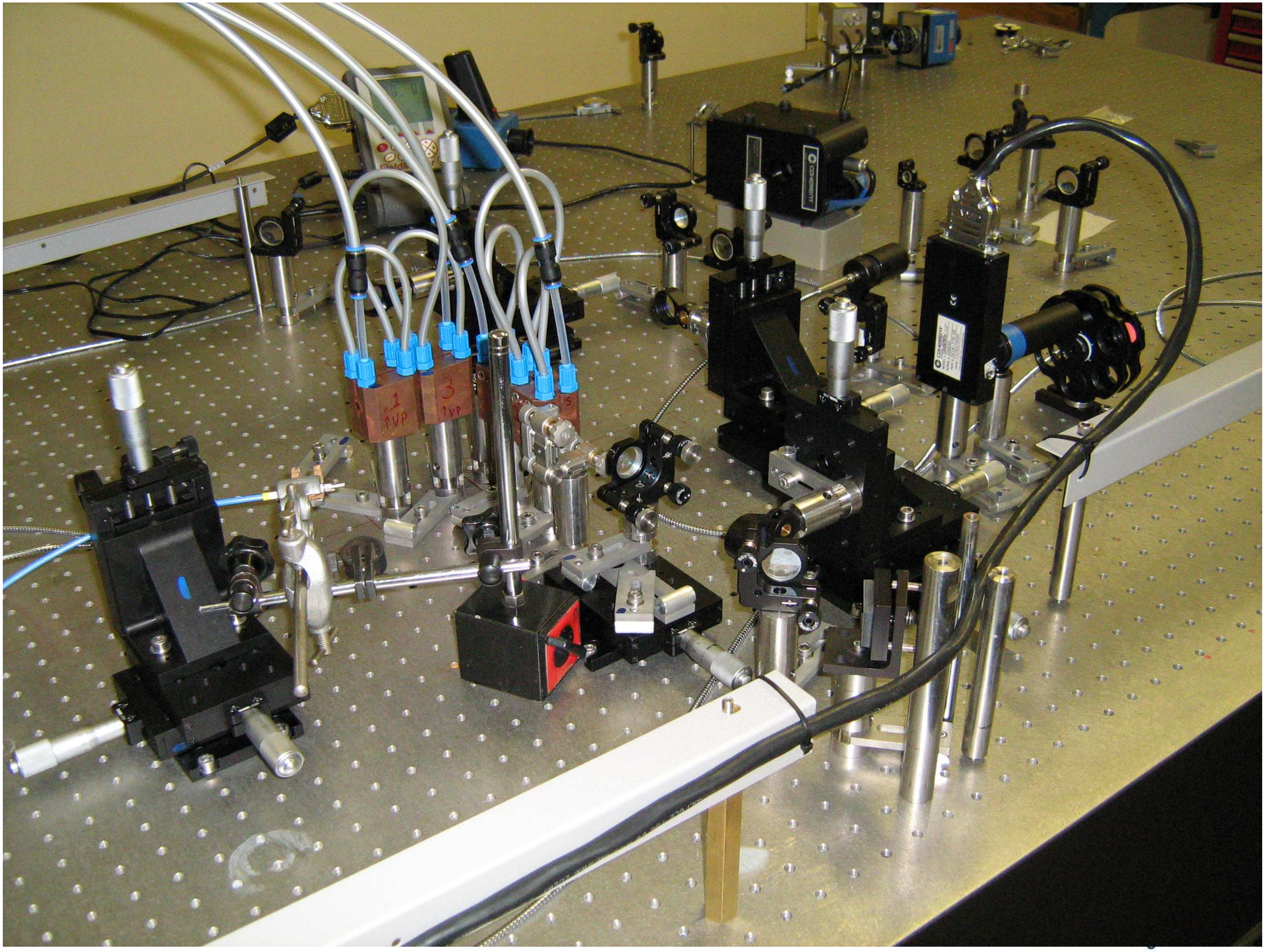
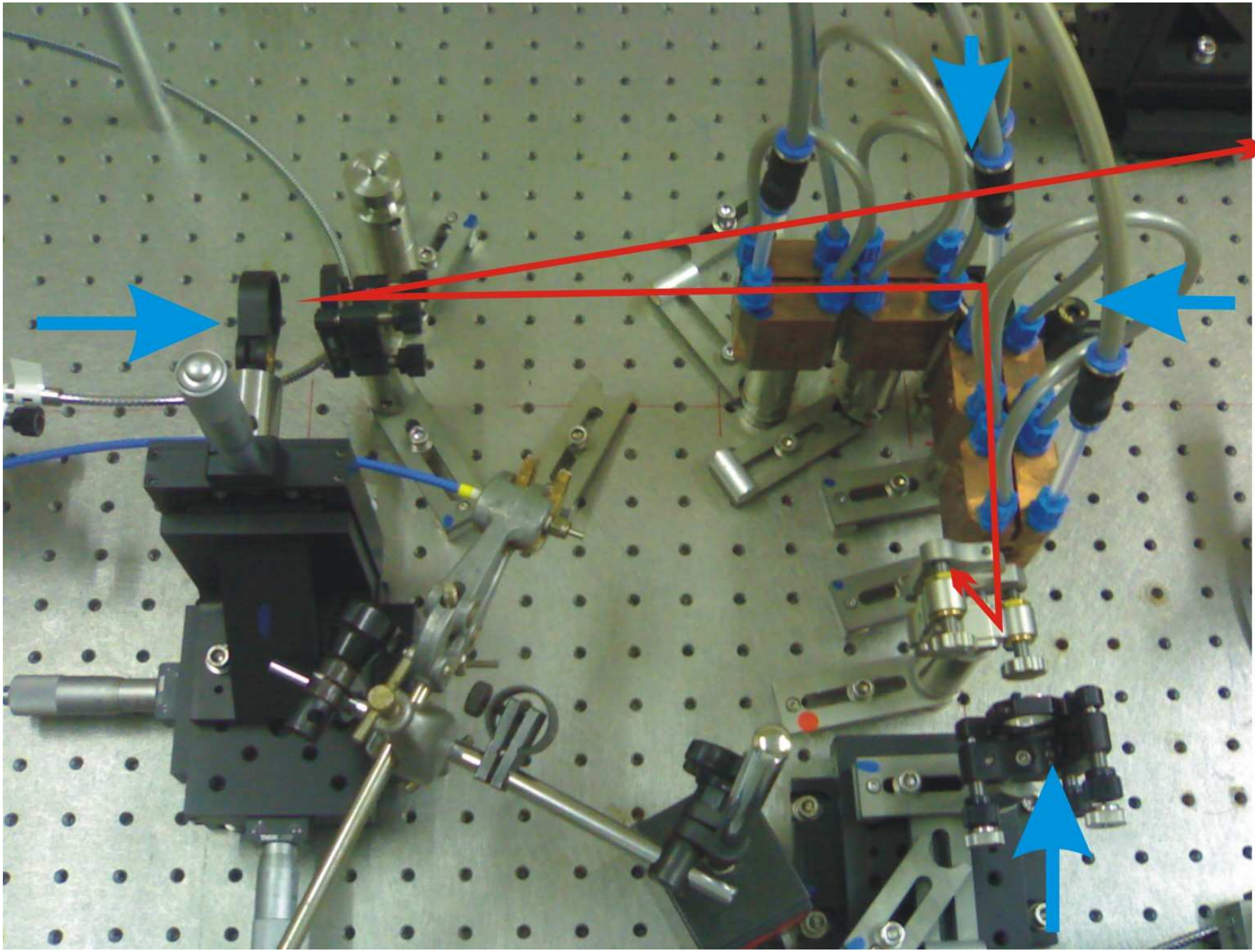
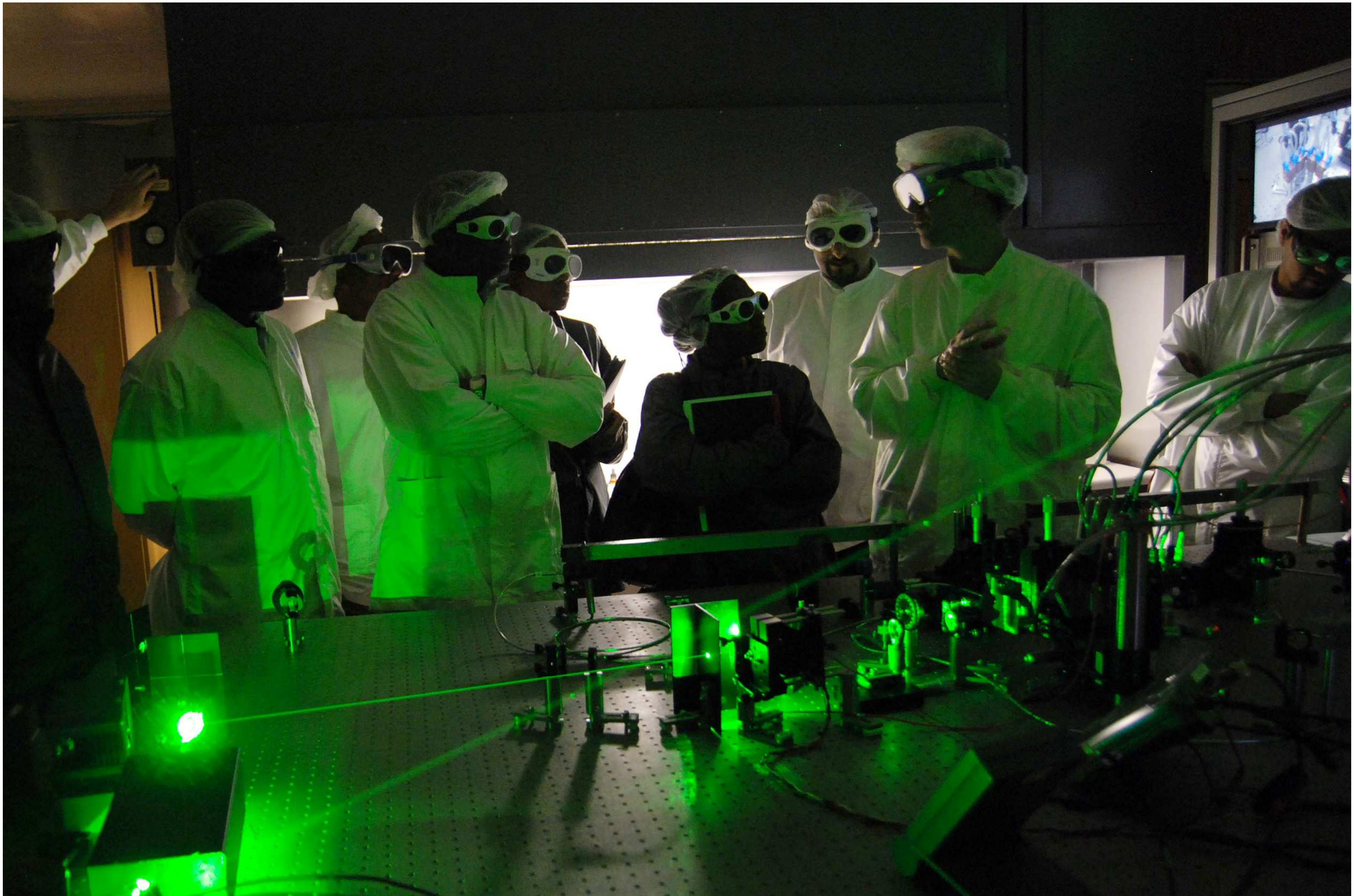






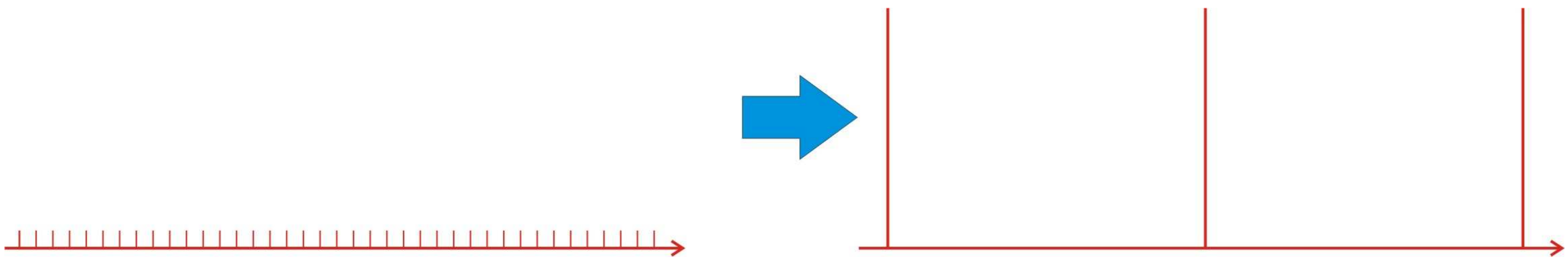
Output Parameters: Prototype

Output obtained from Q-switched laser:

- 12W green- 527 nm
- Pulse Rep rate: 10 kHz
- Pulse length: ~ 150 ns
- Pulse energy: ~ 2 mJ

Conceptual Laser Design

How do we get from 100's of MHz low-energy to kHz high-energy in mode-locked Q-switched lasers?



Seed Laser

Final Output

Steps:

1. Pulse Selection
2. Amplification

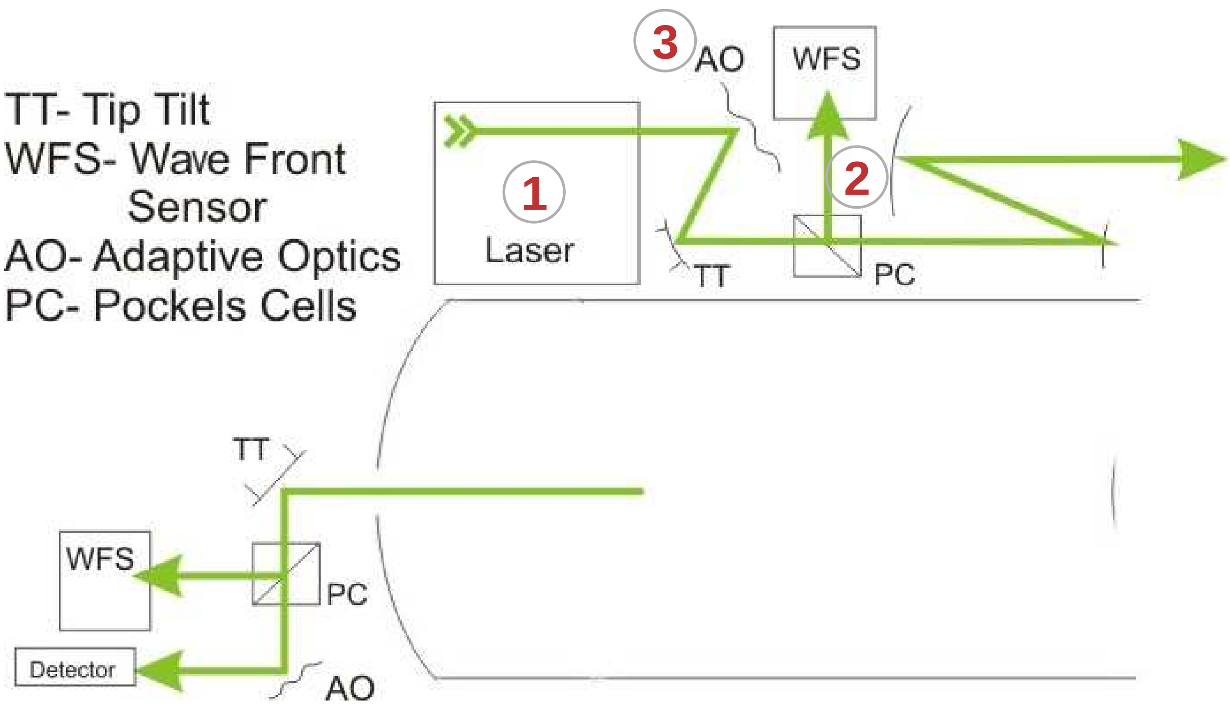
Proposal for new optical subsystem

- Compact, light-weight diode-pumped laser mounted onto telescope
  - Pump diodes separately with light delivered to laser through multi-mode fibres
  - Very good beam quality
  - Own smaller telescope for outgoing beam (e.g. ~40 cm diameter)
  - High-rep-rate operation

- Adaptive optics to reduce laser divergence and field of view independent of seeing conditions.
  - Laser itself creates guide star through time gating to return from higher atmosphere
  - With a 30 cm outgoing beam, a divergence of ~0.5 arcsec could be achieved.
  - This gives a factor 4 improvement compared to 1 arcsec, much more compared to most current systems.
  - The reduced field of view would reduce noise by a similar factor

- Automatic pointing system ensures optimum overlap of laser and telescope field of view.

Proposed system: outgoing laser



- Laser with good beam quality
- Time-gated detection of wave front through laser telescope
- Adaptive optics to correct laser divergence
- Very low laser divergence
- Factor 3 to 10 improvement of intensity on moon

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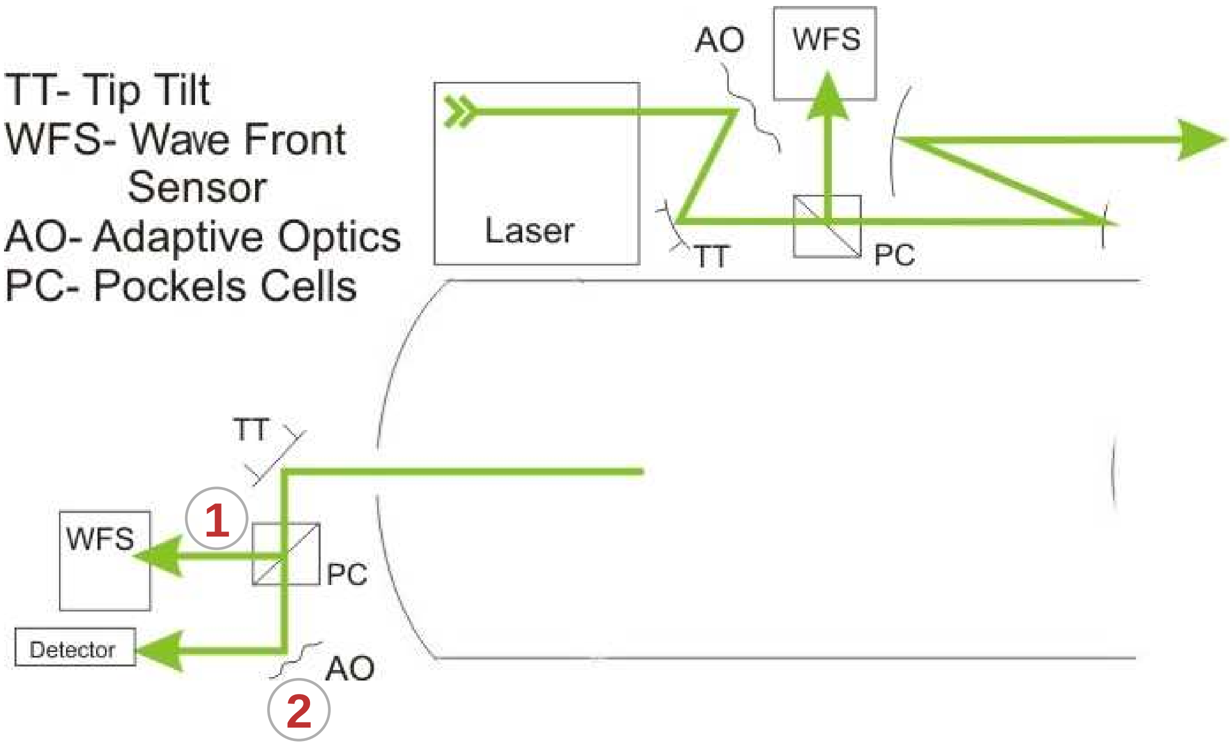
Proposed system: receiving



- Time-gated detection of wave front through main telescope
- Adaptive optics to improve receiving resolution
- Can significantly reduce field of view
- Factor 3 to 10 reduction of noise

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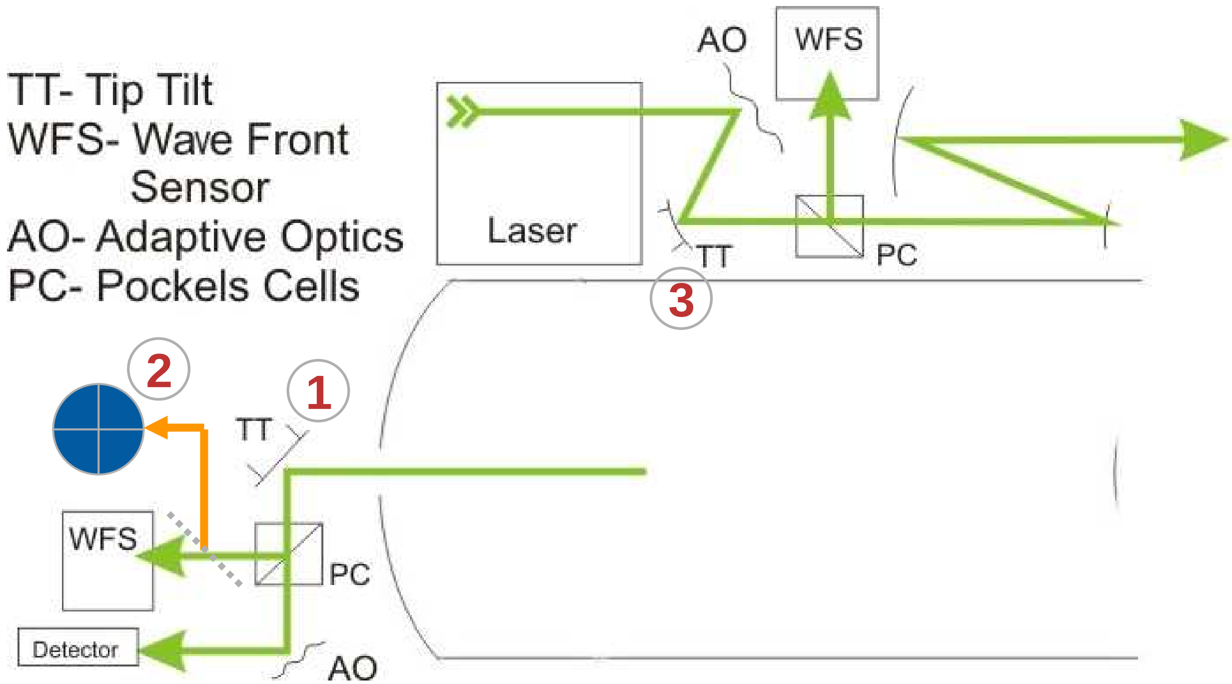
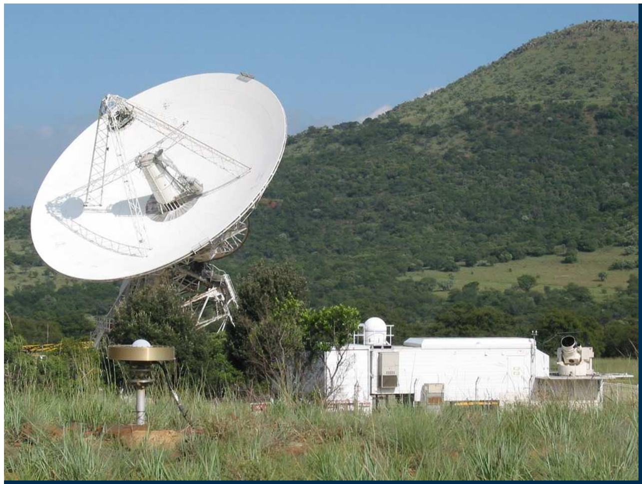
Proposed system: pointing and alignment

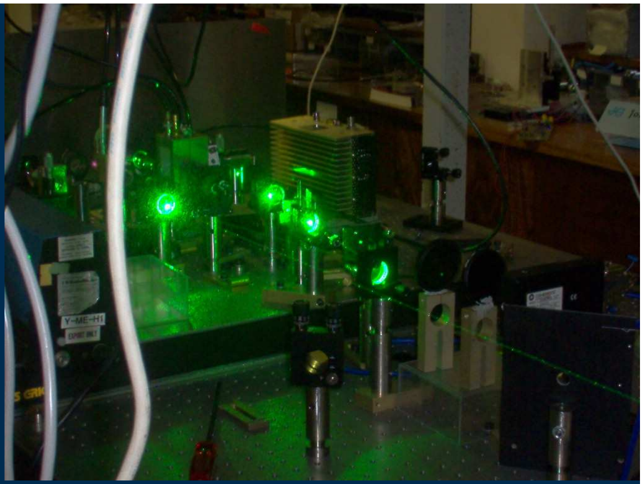


- Tip-tilt mirror to actively fine-adjust pointing to retro-reflector
- Time-gated detection of laser direction from atmospheric far-field scattering
- Tip-tilt mirror to adjust laser pointing to main telescope
- Always perfect alignment of laser beam to main telescope

Conclusion

- Upsizing of current technology will not allow millimeter level accuracy
- A new laser design for better beam quality is necessary
- A novel 'dual-telescope' system is a feasible option
- Adaptive optics will correct for transmit and receive path efficiencies by lowering final beam divergence
- Automatic alignment and pointing control will significantly reduce system errors and increase accuracy





Thank you

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