Lasers for Multiwavelength Satellite Laser Ranging

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Assuming the atmospheric dispersion, to find the right laser for multiple wavelength millimeter SLR, one can consider the Nd:YAG / SHG / THG, Nd:YAG / SHG / Raman in Hydrogene/1S/1aS [1], Raman in Methane /1S and the Titanium Sapphire fundamental / SHG, all of them at different repetition rates. The available detectors have to be considered. For the visible range we did examine Silicon [2], GaAs, GaAsP and GaP based SPADs, for the eyesafe SLR Germanium [3], GeSi and InGaAs based SPADs. Using the Quantel Laser 30 mJ / 1,06 _m, 35 psec, different Raman tubes filled by Hydrogen at different pressure, different focusing lens, we were getting 8 mJ / 0.68 _m, 1 mJ / 0.45 _m [4]. Considering the eyesafe SLR using Methane we were getting 3 mJ / 1.54 _m [5].

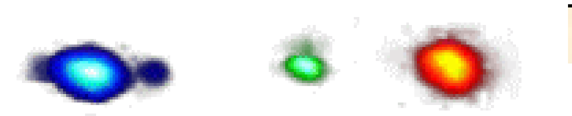
Our optimization of the four wavelengths Raman laser at 1.064, 0.53, 0.68 and 0.45 _m gives 60, 20, 7, 2 mJ at 20 Hz for 35 psec pulses. The laser is dedicated for the new Shanghai SLR station.

Using Raman, one has to be cautious at higher pumping levels. Either to monitor the far field beam structure (CCD) or pulse structure (streak) might be a proper diagnostics.

The support provided by the Grant Kontakt ME414 is greatly appreciated.

References:

1. J.Gaignebet,J.L.Hatat,K.Hamal,I.Procházka,H.Jelínková, *Two wavelength ranging on ground target using Nd YAG 2HG+Raman 0.68um pulses*, The Sixth International Workshop on Laser Ranging Instrumentation, Juan les Pins, Sept.1986
2. G.Kirchner, F.Koidl, J.Bla_ej, K.Hamal,I.Procházka, *Time Walk Compensated SPAD: Multiple Photon Versus Single Photon Operation,* Proceedings of the European Symposium on Aerospace Remote Sensing, published in **SPIE 3218-07, (**1997)
3. I.Procházka, K.Hamal, H.Kunimori, B.Greene, *Large aperture Germanium detector for picosecond photon counting in the 0.5 to 1.6 um range*, **Optics Letters,** Vol.21 (17), September 1, (1996), page 1375-1377
4. Karel Hamal, Josef Blazej, Ivan Procházka, Fu Min Yang, Jingfu Hu, *Raman laser for multiple wavelength satellite laser ranging,* presented at the conference Photonics, Prague, June 2002
5. B.Greene, H.Kunimori, K.Hamal, I.Procházka, *Atmospheric dispersion monitoring using 0.53 um and 1.54 um satellite laser ranging,* Technical Digest Cleo/Europe '96, Optical Soc.of America, IEEE Catalog Number 96TH8161, page 221, (1996)



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presented at

13th Int. Laser Ranging Workshop "Toward Millimeter Accuracy"
Washington D.C., October 2002

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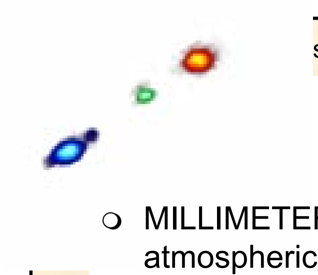
[3] Observatoire de la Cote d'Azur, Grasse, France



Goals

- MILLIMETER PRECISION ranging
  atmospheric studies

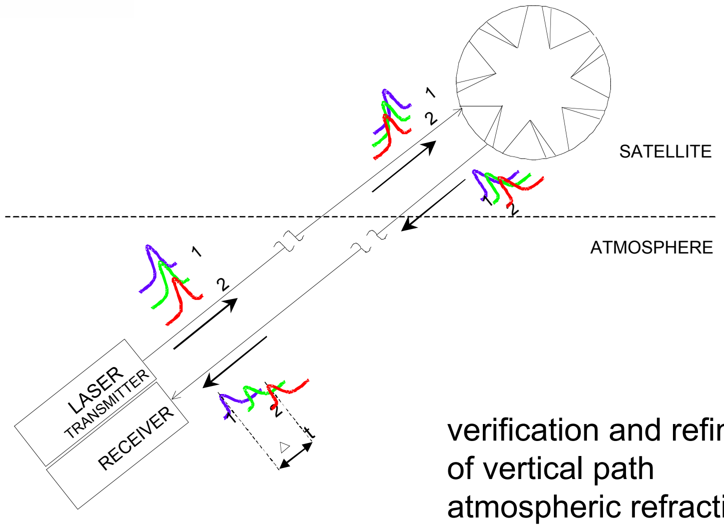
- WORLD NETWORK
  Prague, Graz, Shanghai, Tokyo, FP6

- LASER REQUIREMENTS
  - pulse length < 50 psec
  - energy > 1 mJ , CLEAN TEM 00
  - multi wavelength, ~ 1 psec time synchro.

- LASER CANDIDATES
  - Ti-Sapphire + SHG
  - Nd YAG + SHG + Raman in gas

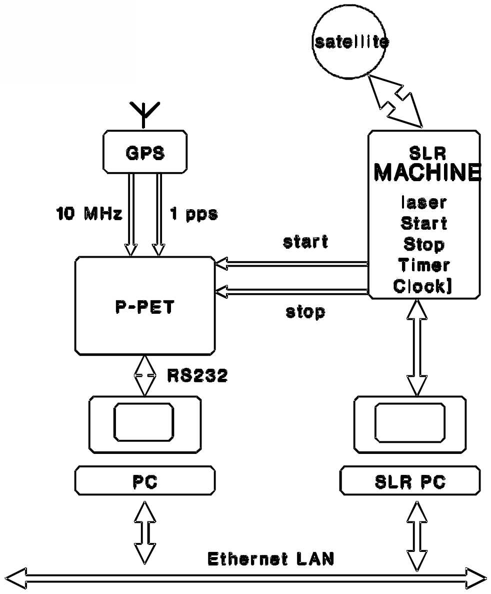
Satellite Laser Ranging

Why multiple wavelengths?

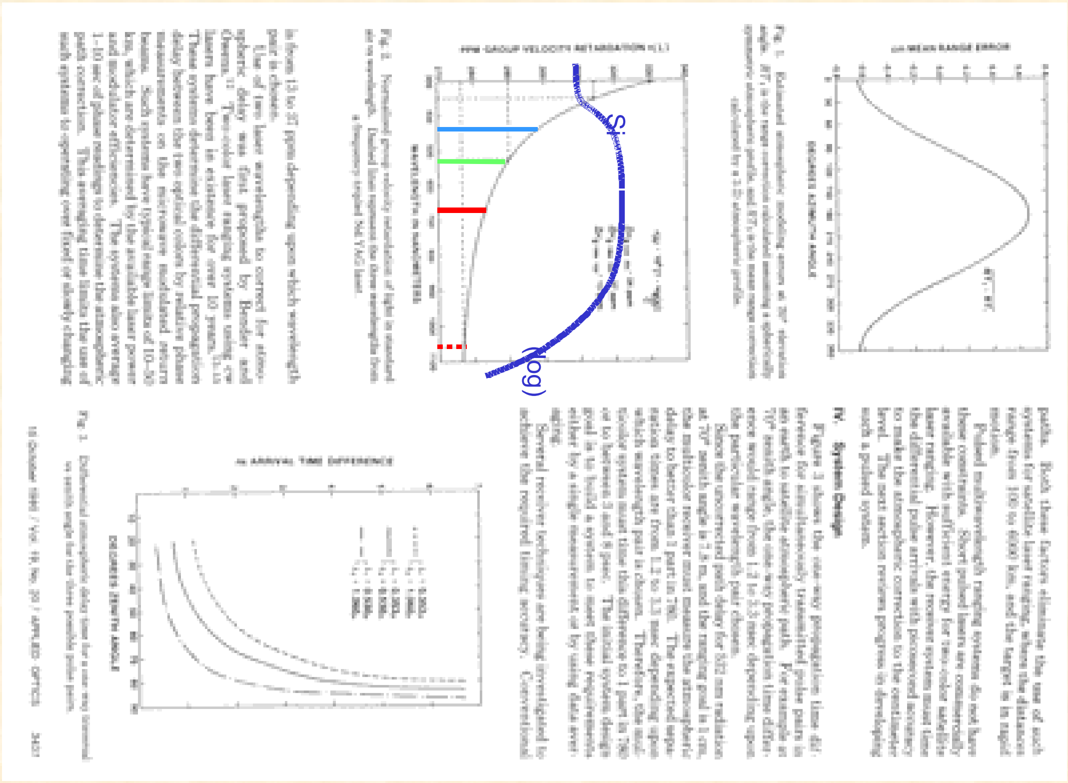


verification and refinement
of vertical path
atmospheric refraction models

Portable Calibration Standard Block Scheme



minicoll



Group Atmospheric Refractivity vs. ë

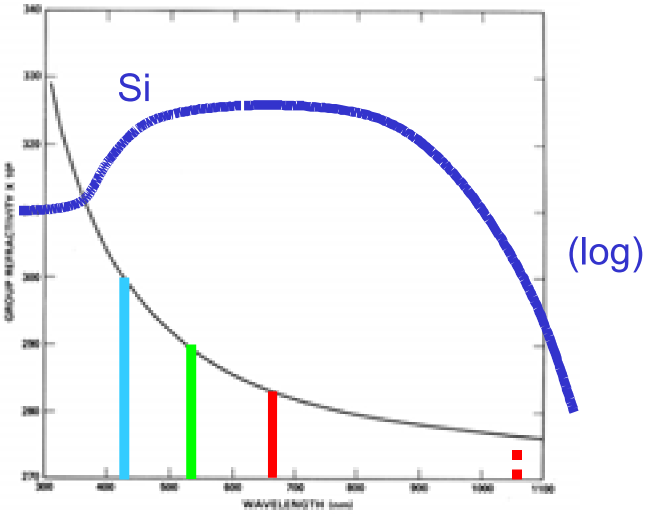
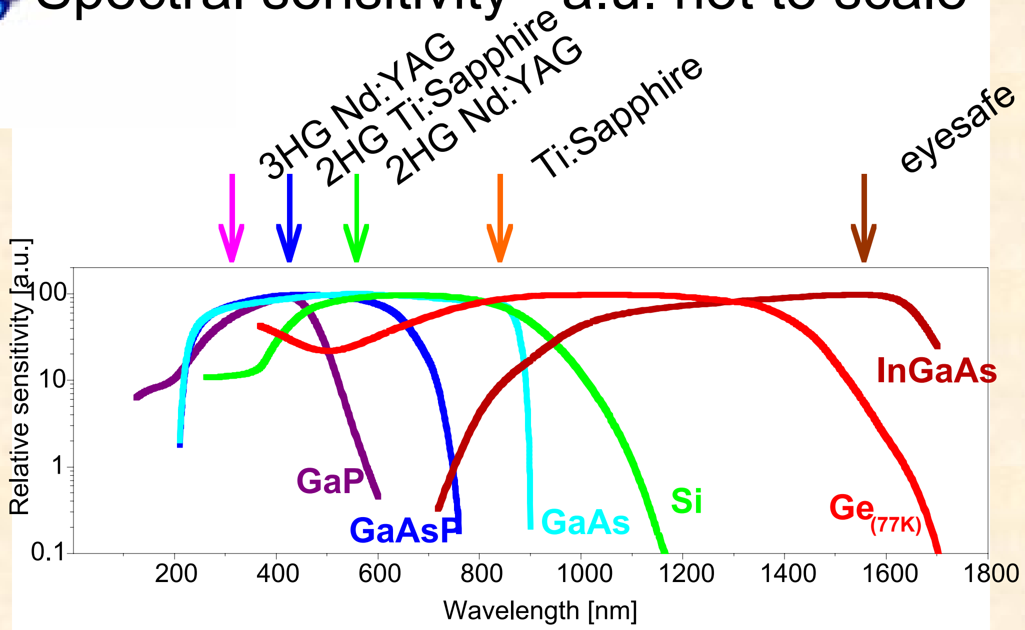


Fig. 2. Group refractivity of air at $P = 1013.25$ mbar, $T = 15°C$, and RH = 50 percent.

Spectral sensitivity - a.u. not to scale



Raman laser history

- J.Gaignebet, K.Hamal, I.Prochazka, J.L.Hatat
  ground target ranging, Prague
  green, red
  Workshop Antibes, 1986

- K.Hamal, I.Prochazka, G.Kirchner, F.Koidl
  satellite, ground ranging, Graz
  green, red, blue
  IQEC , Vienna,, 1992

- H.Kunimori, B.Greene, J.Guilfoyle, K.Hamal, I.Prochazka
  satellite, ground ranging, Tokyo
  infrared eye safe, green
  CLEO Europe, Hamburg, 1996

Multiple wavelengths pair candidates

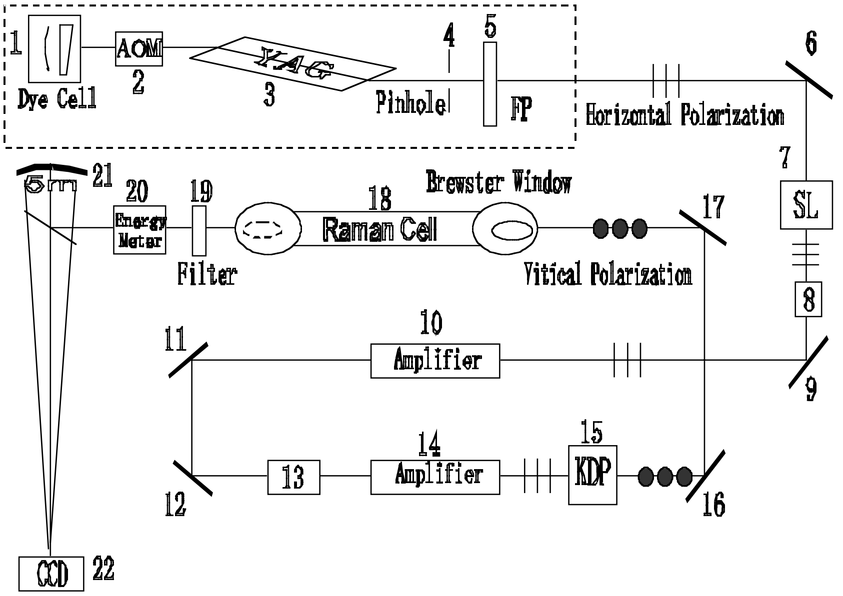
- Titanium Sapphire – fund. / SHG, 846 nm / 423 nm
  (Germany, Swiss)
  + high atmosphere transmission and dispersion
  – laser complexity (oscillator)
- Nd:YAG + Raman in CH_4 / SHG, 1543 nm / 532 nm
  (Japan)
  + eye-safe 1543 nm
  – Germanium, InGaAs detectors
  – to be optimized (Prague, Tokyo)
- Nd:YAG SHG + Raman in H_2, 532 nm / 680 nm / 436 nm
  + Si detector optimum
  – to be optimized (Prague, Graz, Shanghai)

Budget Link

$$\varepsilon = \eta^2 f Q \left(\frac{n d^2}{R^2 \Phi^2} \right) \left(\frac{D^2}{R^2 \phi^2} \right)$$

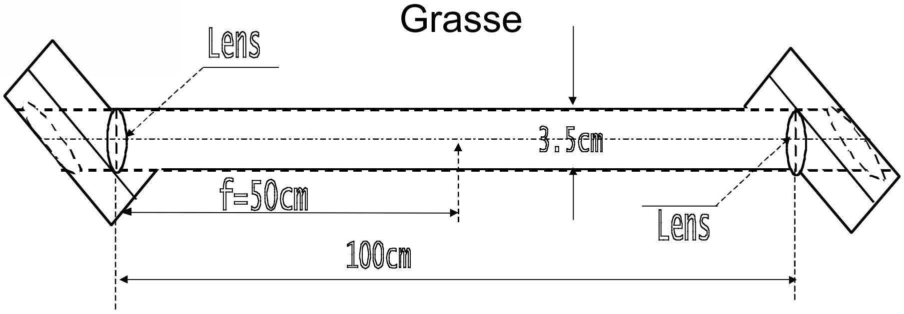
ε - link efficiency
Φ - atmospheric divergence
ϕ - corner cube divergence
D - diameter of the collecting telescope
d - diameter of the n corner cubes in array
R - distance to the satellite
η - telescope/atmospheric transmission efficiency
f - receiver throughout
Q - detector efficiency

Block Scheme

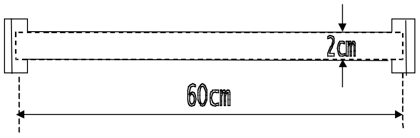


Raman Tubes

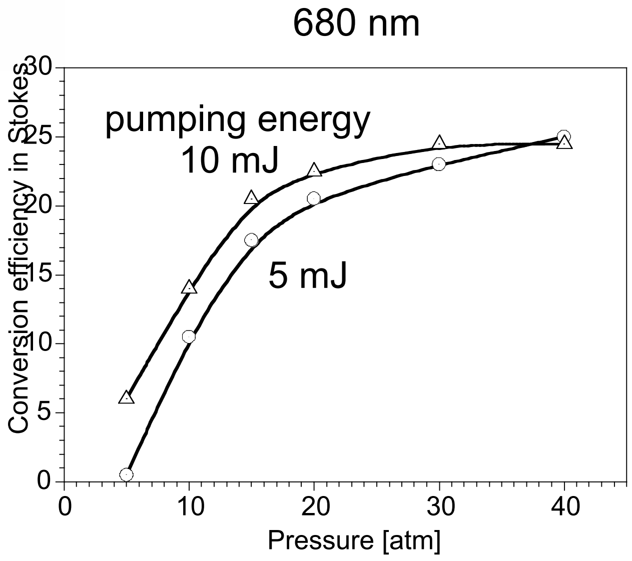
Grasse



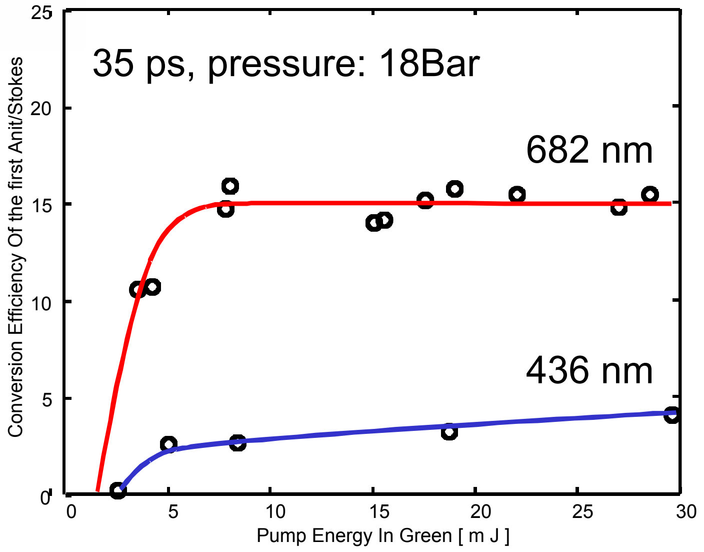
CTU



Conversion Efficiency vs. Pressure



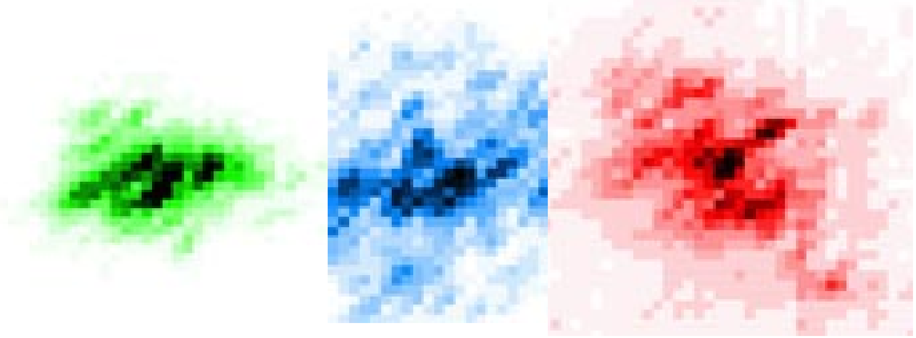
Conversion Efficiency vs. Pump



Raman Stokes far field beam structure

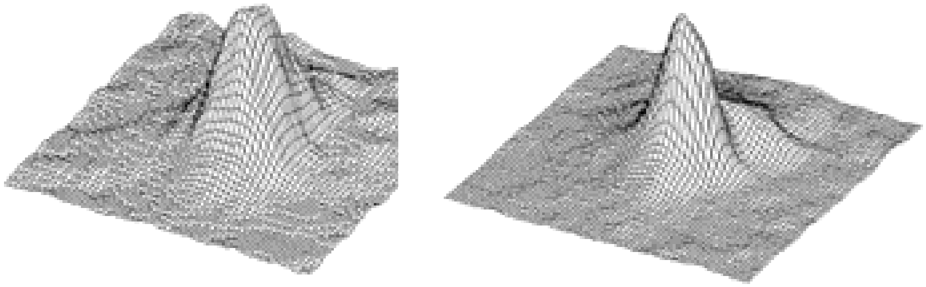
35 ps, 30 Bar

532 nm 436 nm 680 nm



10 mJ 2.5 mJ 0.4 mJ

Raman Stokes far field beam structure



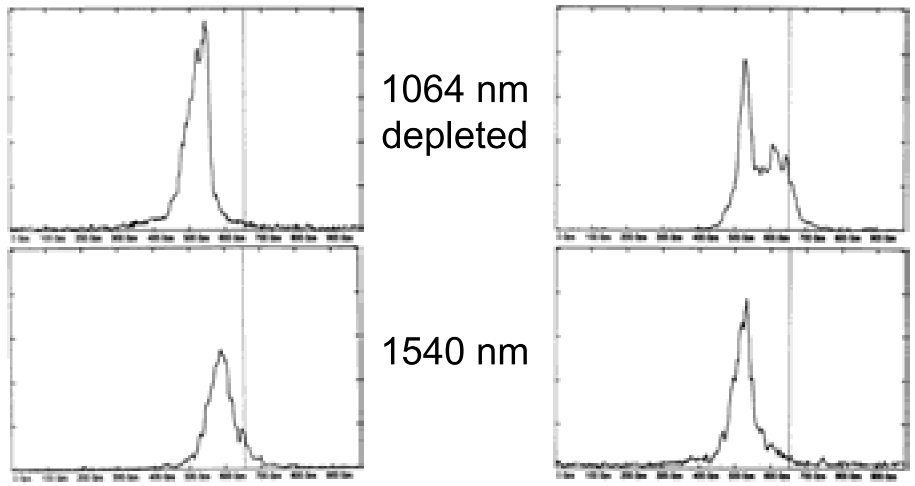
1064 nm 1540 nm

Blazej et al, Photonics, Prague, 2002

Raman Stokes temporal profiles

1064 nm shifted in methane, 1ns/screen

near above threshold | high above threshold



Kunimori et al, Tokio, 1996

Conclusion

- Raman Stokes and AntiStokes generation in methane and hydrogen has been investigated
- for SLR application the Raman generator must be operated just above the threshold to preserve the spatial and temporal structure required
- the SLR applicable conversion efficiency is 5÷10%
- Raman conversion optimized in a range 35÷200 psec pump laser pulse length