AFIRE: Fibre Raman Laser for LGS AO

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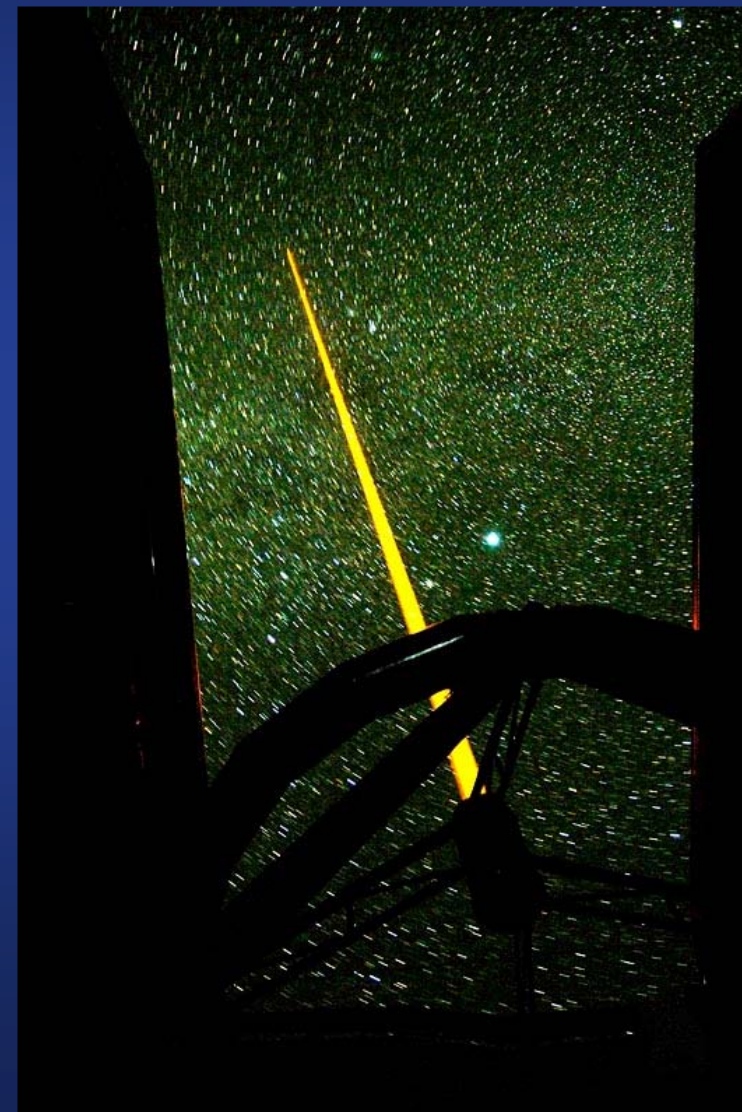
A joint effort between ESO and industry

Targeted goal is the AOF/4LGSF

Entry point for ELT lasers

- Why fibre lasers?
- Which fibre lasers?
- AFIRE design and associated risks
- Status of the AFIRE development



Approaches to 589nm lasers

- Dye lasers have produced 589nm at Keck, Lick and ESO.
- To produce 589nm, there are no direct transitions of solid state elements (Samarium on the right fiber glass host ??)
- Therefore non-linear effects such as sum-frequency or frequency-doubling have been used in solid state laser (2 photon processes)
- 1319+1064 is used in the LMCT and SOR systems, and in the U.Chicago solid state free space laser system.
- 1583+938 is used in the fibre laser jointly developed with LLNL
- 1178+1178 is used in the AFIRE fibre laser (1121->1178 via Raman shifting)
- All solid state lasers at 589nm therefore use <u>non linear crystals</u>

Non linear crystals

- If the linewidth is sufficiently narrow, cavities can be built around a non linear crystal to increase the conversion efficiency to ~25%. Usually BBO or LBO, which we find also in 532nm lasers.
- Single pass Periodically Poled non-linear crystals are a new technology which allows to simplify the laser very much.
- a 20mm long PPKTP has an acceptance bandwidth of 45 GHz
- PPNLC Efficiencies between 20% and 40% have been reported
- The converted powers in PPNLC so far range up to 15W QCW
- The thermal effects in the PPNLC can be destructive and depends largely on the purity of the crystal, and on the quality of the poling
- The crystals used for PPNLCs are KTP, MgO-SLT, SLT, LN, KTA

Fibre lasers: the best choice for future Observatories

- **Compact** (rack-mounted, can be placed next to LT)
- **Efficient** (diode-pumped)
- **Robust & reliable** (commercial availability of key components from telecom industry)
- **Simpler than other schemes** (better MTBF and cost)
- **Alignment free** (real turnkey operation)
- **In-built fibre delivery at LT** (no need for beam relays)
- **Diffraction-limited output**
- **Power scalable** (>100W fibre lasers are available)

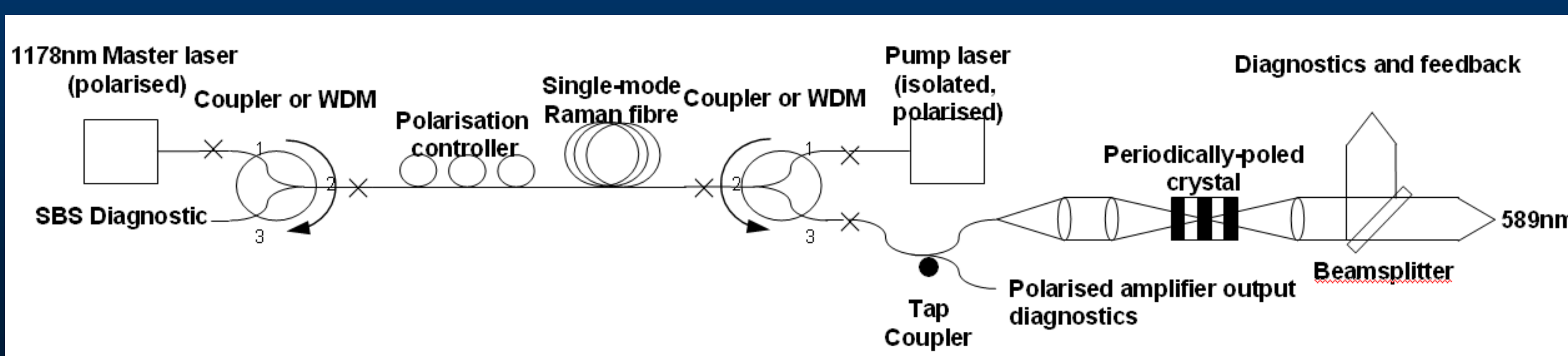
Which Fiber Lasers?

- The ideal would be a rare-Earth doped double clad fiber laser, such as the Yb, Bi or Nd fiber lasers. They have demonstrated up to >500W, and cost ~1KEUR/W. Interesting would be to try Samarium doping on special fibers, or Bi fibre lasers, especially for ELT pulsed formats.

- For the AFIRE we chose a pure fused silica fibre pumped with an Yb fibre laser at 1121nm, to give via Raman shifting 1178nm photons (30 W achieved so far)

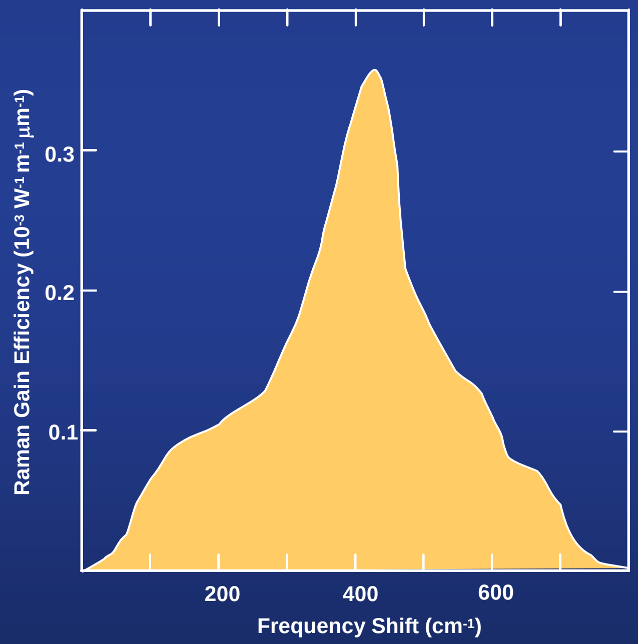
- Raman shifting in single mode fibers can be very efficient at high powers

- We frequency double using PPNLC.



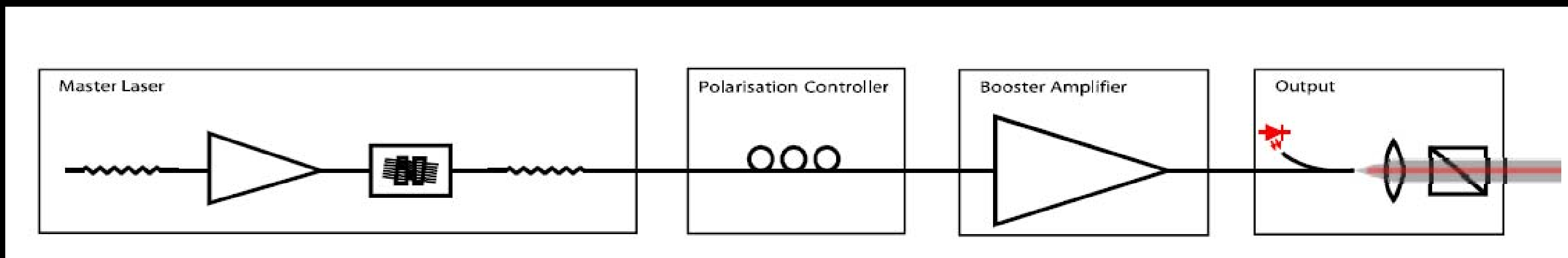
Relevant features of SRS

- by proper selection of the pump frequency, one can realise gain in any signal band (Stokes shift in silica is ~ 13 THz)
- Raman gain in silica extends over a broad and continuous band range (~ 5 THz), which simplifies the finding of a proper pump source



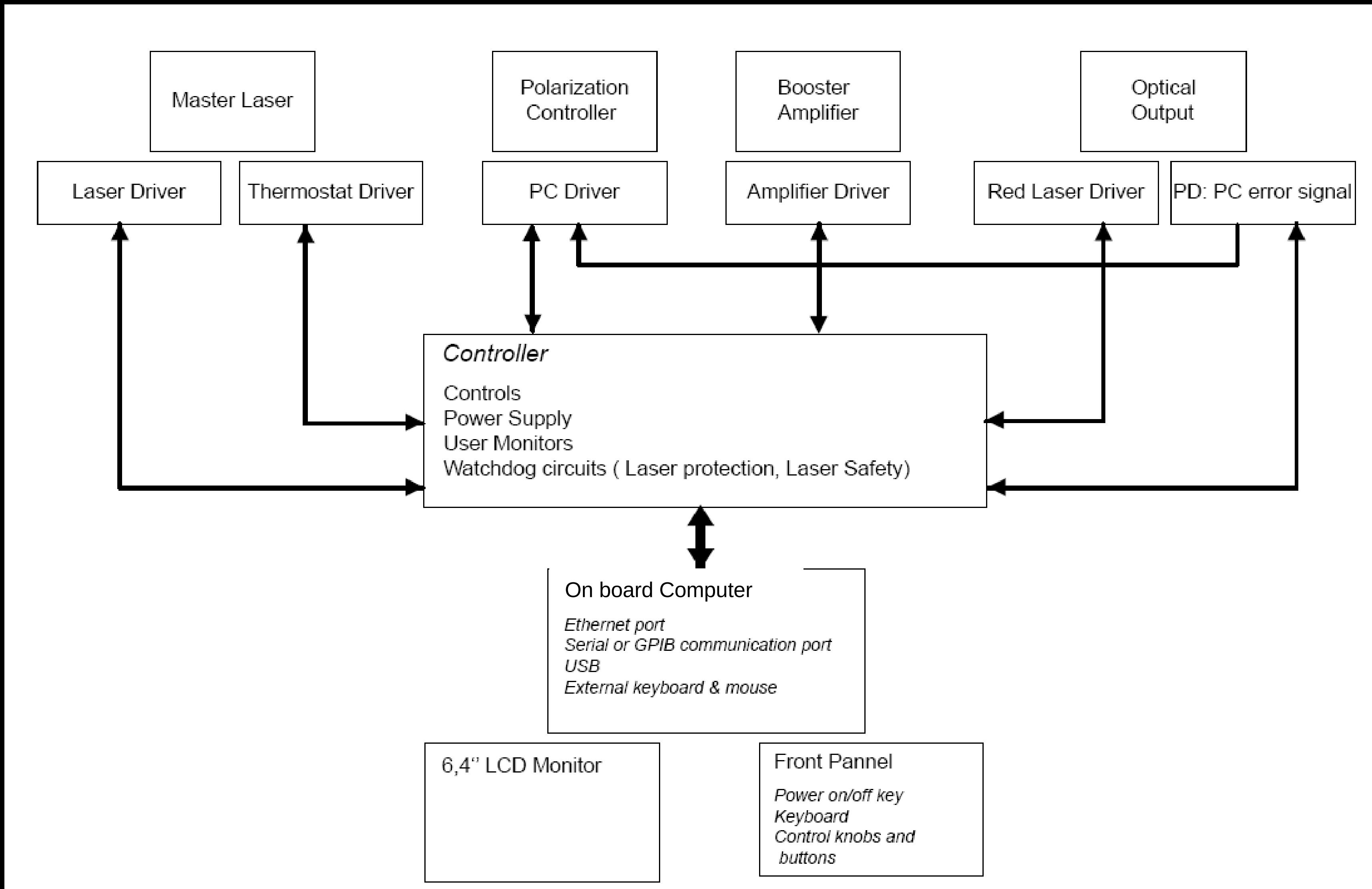
- Since the Raman gain profile is inhomogeneously broadened, all of the broadband pump power within the gain profile can contribute to a narrowband signal
- Raman amplification generates little noise in the absence of pump light, i.e., Raman amplifiers are almost always "fully inverted", regardless of pump rate. Thus, the noise properties of the Raman amplifier is determined by the pump only
- The nonresonant nature of Raman amplification makes this process insensitive to temperature
- SRS is a polarisation-sensitive process

AFIRE Requirements



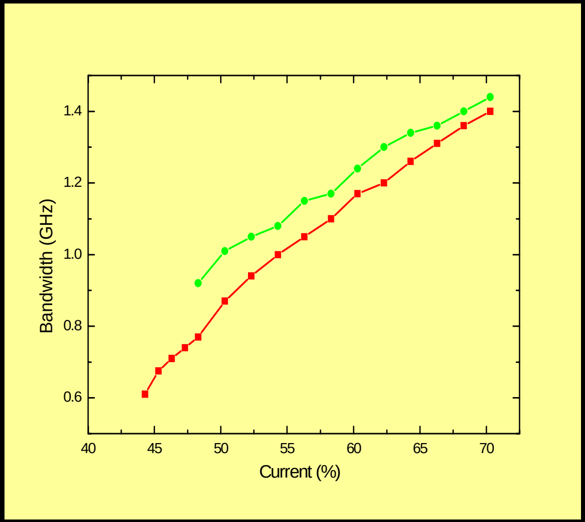
Parameter	Units	Minimum	Typical	Maximum
Output Power (589nm)	W	10 (5+5)	12	20
Output power (1178nm)	W	40 (2x20)	50	60
Tuning Range	GHz	20	30	-
Tuning Speed	GHz/sec	5	7	-
Linewidth at 589nm	GHz	0.2	0.5	1.0
Output linear polarization	%	97	99	-

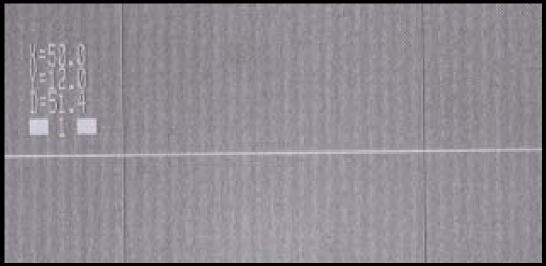
1178nm Raman Laser Control scheme



Risk areas

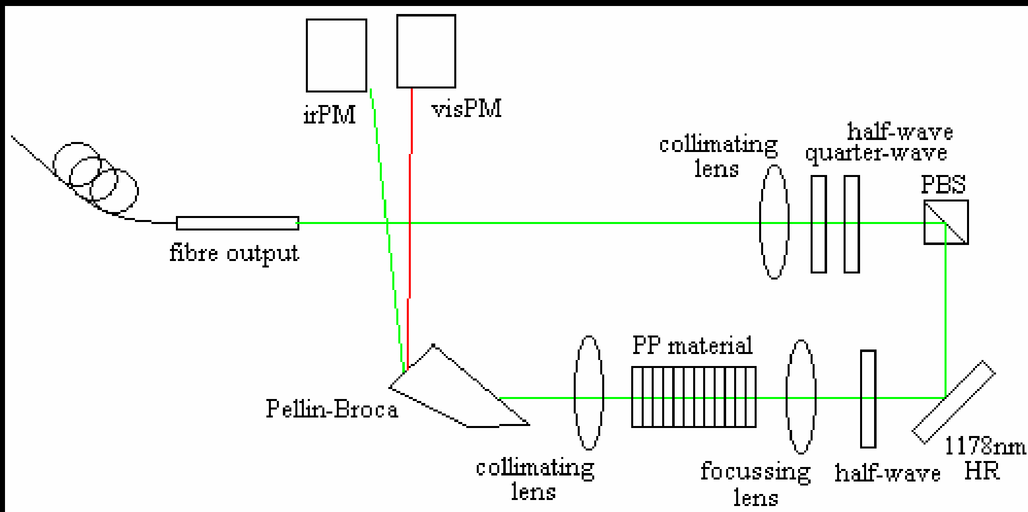
- We want 1 GHz linewidth. The Raman amplification tends to broaden the linewidth, via FWM effect
  - The FWM effect is proportional to the input master linewidth - Found solution: make it narrower
- Too narrow linewidth can start the SBS, and it has to be quenched
  - This effect conflicts with FWM - Found solution: QCW > 5MHz, pulses shorter than SBS onset time
- The PPNLC may not be stable or even get damaged at the required conversion powers
  - PPNLC with the powers of interest for us have been demonstrated – working to characterize the various effects, large PPNLC sample



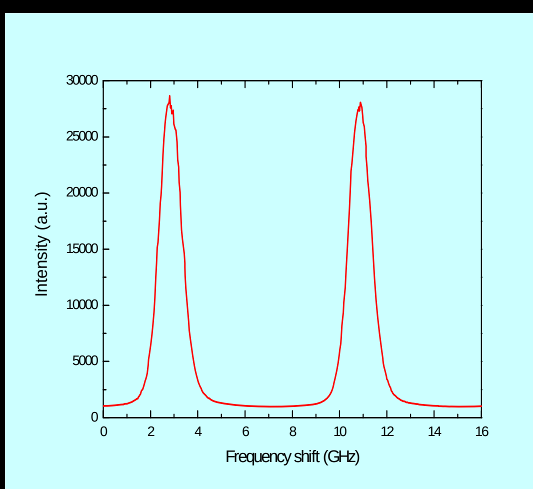


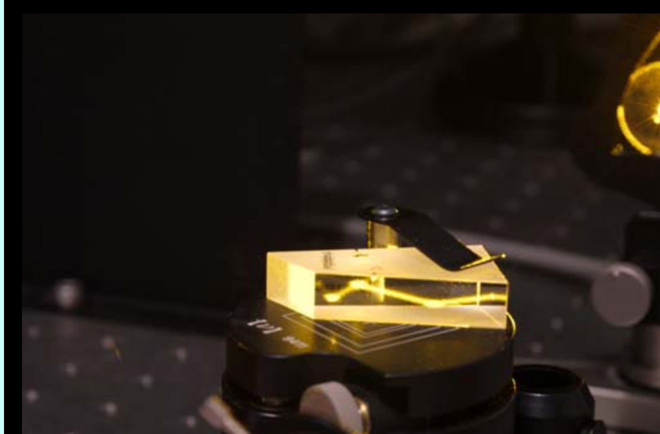
AFIRE Lab at ESO

Yan Feng and Luke Taylor



Lab setup





AFIRE status

- Produced 30W CW at 1178nm with the first engineering unit
- at 20W CW 1178nm, linewidth is 1GHz at 1178nm
- We will receive a QCW RFL unit with narrower linewidth in Dec
- Received and tested several PPNLC from different vendors. More to test.
- Very interesting work in the new field of PPSLT
- Produced 4.2W CW at 589nm, with 18W input (23% C.E.)
- Our goal is to demonstrate by the feb ‘07 >5 W CW with appropriate linewidth
- Our final goal is to have a completely engineered AFIRE by 2008 to field-test it.

Conclusions

- We are progressing so far at the foreseen speed toward a 10W CW 589nm fiber laser
- The parallel developments in the area of PPNLC are crucial, our powers have been demonstrated
- The 30 W narrow linewidth Raman fibre laser is a world premiere
- The converted power, 4.2W at 589nm at our linewidths, is also unprecedented with fibre lasers, and better than current LLNL results.
- A QCW option is easily possible if it will increase the PPNLC conversion efficiency
- A study contract for a pulsed version of the AFIRE [ELT] will be started in the next months