High Power Vanadate lasers

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Aims

1) To develop new *techniques to mount* laser crystals,

2) compare the *lasing properties* (like thermal lens) of two equally doped, high power *Nd:YVO$_4$ and Nd:GdVO$_4$* lasers,

3) build a 1 $\mu$m vanadate laser with average output power exceeding 100W,

4) build a 1.3 $\mu$m vanadate laser with average output power of around 30 to 50 W.
Motivation

1) Poor thermal contact between crystal and mount → stronger thermal lenses and thermal stress → bad beams and/or crystal damage.

2) Nd:GdVO$_4$ spectrally very close to Nd:YVO$_4$. Much uncertainty about the thermal properties → Directly comparing two equally doped crystals under lasing conditions will contribute to this debate.
3) No end-pumped vanadate the 100W range.

4) There is a strong interest in this for numerous applications in industry and the medical field. End-pumped vanadate lasers are a good candidate, especially for Q-switched lasers.
Mounts

1\textsuperscript{st} generation

- Low temp. solder (~ 93°C)
- Silver thermal epoxy (~ 80°C)

2\textsuperscript{nd} generation

- Indium between mounts
- Silver thermal epoxy in crystal mount
Thermal lens measurements

- Resonator unstable if $f = L$

- Can determine the thermal lens focal length at various pump power levels by varying the resonator length

- Take slope efficiencies and monitor the exit beam with camera*

*M.J. Daniel Esser et al.
Current Results: Output beam thermal lens

Slope efficiency $\sigma$ pol 250mm resonator

Thermal lens dioptic power ($1/f$)
High Power vanadate laser

1) Pump two laser crystals from both sides using a 140W diode pump (2 beams) and two 75W pumps.

2) Mount crystals perpendicular to each other.

3) The crystals have to be very close because of their large thermal lenses, to keep the beam diameter roughly equal in both.

4) High Average Power at 1 and 1.3 µm and is expected to exceed 100W and 40W respectively.

6) The laser can be also pulsed by using an Acousto-Optic Modulator (AOM) to produce high energy pulses.
Layout for the High Power vanadate laser

New laser diode module, 75 W

Optical fibre
0.4mm core
0.22 NA

140-W diode-laser module

Optical fibre
0.8mm core
0.22 NA

Pump beam 1

R = 50%

Optical fibre
0.4mm core
0.22 NA

Pump beam 2

Nd:YVO₄
0.15% doping

Nd:YVO₄
0.15% doping

Back reflector

Output coupler

AOM

LRI
Laser Research Institute
Mount positions in resonator
Polarization line selection of vanadate crystals

If a birefringent laser crystal has a wedge and is cut correctly the two polarizations can be spatially separated.

Only one polarization can therefore be aligned in the resonator

\[
\begin{align*}
\sigma E \perp c & \quad n_0 = 1.972 \\
\pi E \parallel c & \quad n_c = 2.215
\end{align*}
\]
Conclusions

1) New mounting techniques have been developed for square crystals.

2) Thermal lens measurements- a direct comparison between Nd:YVO$_4$ and Nd:GdVO$_4$’s thermal properties during lasing can be made at two important wavelengths.

3) Pi-polarisation $\rightarrow$ Weakest thermal lens $\rightarrow$ Ideal for high output power levels
Future Work

• Determine the **thermal lens focal lengths** over a wider range of pump powers and for 1 and 1.3 µm and better method: beam scanner

• **Compare the thermal lens behavior** of Nd:GdVO\(_4\) and Nd:YVO\(_4\) at both polarizations.

• Build high average power and high energy vanadate lasers

• Waiting for: 2\(^{nd}\) generation crystal mounts power supplies for 75W diode pumps