AXIOMA experiment

Measurements on Er^{3+}:YLF

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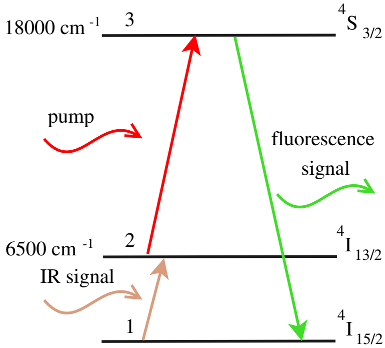
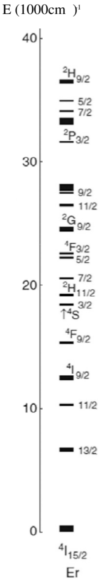
IRQC scheme in Er^{3+}

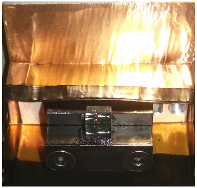


features

- GSA absorption in 1450 ± 50 nm band;
- long lifetime of $^4I_{13/2}$;
- pump wavelength $\sim$840 nm;

Er^{3+}:YLF data





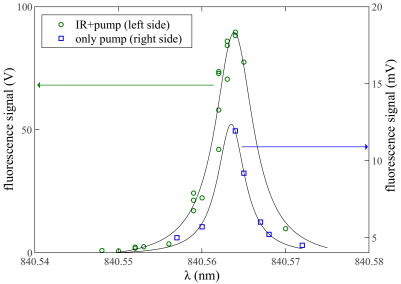
Er:YLF characteristics

- energy gap $\sim 10.5\,\mathrm{eV}$
- phonon energy $\sim 500\,\mathrm{cm}^{-1}$
- lifetime of $^4I_{13/2} \sim 20\,\mathrm{ms}$
- lifetime of $^4I_{11/2} \sim 5\,\mathrm{ms}$
- fluorescence ratio $^4S_{3/2} \rightarrow ^4 I_{13/2}$ $\sim$0.3
- fluorescence ratio $^4S_{3/2} \rightarrow ^4 I_{15/2}$ $\sim$0.7

Er^{3+}:YLF

former measurements...

S/N∼5000



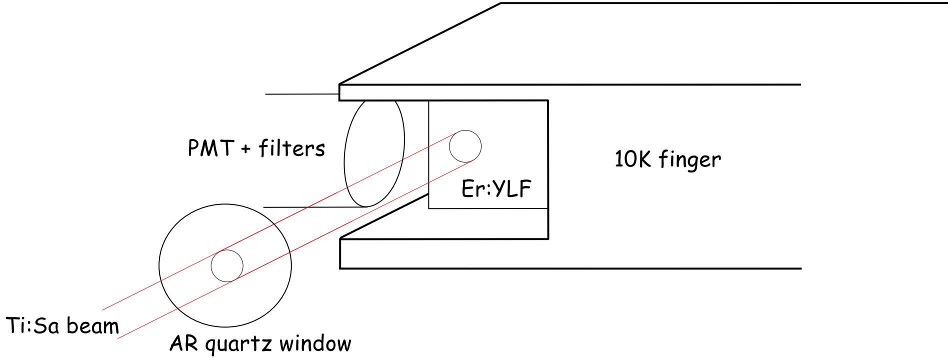
...then something bad happened!

S/N∼500

New set-up, new crystal

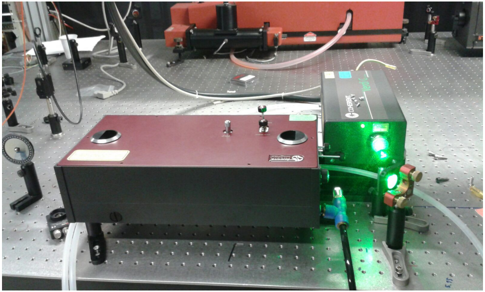
tests

- new optical windows
- new mounting
- new glue
- new crystal
- different section of laser beam



new Ti:Sa laser

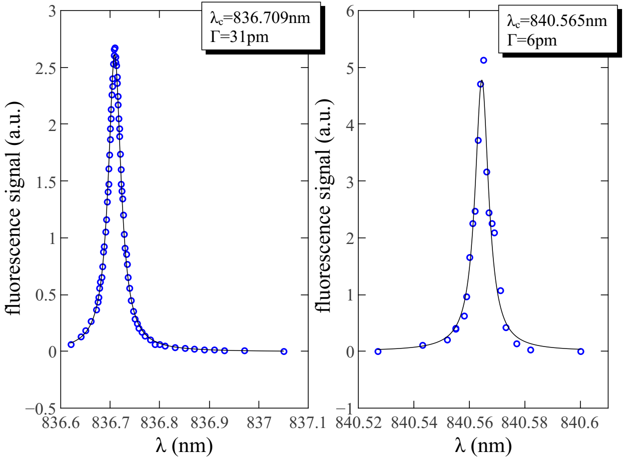
Avesta project Moscow



features

- tunability: (690-1015) nm
- linewidth: $< 2\,\text{GHz}$
- max output power: 1.5 W @780nm with 6.5 W pump
- polarization: $\sim 100\%$

lines in the $^4S_{3/2}$ manifold



literature

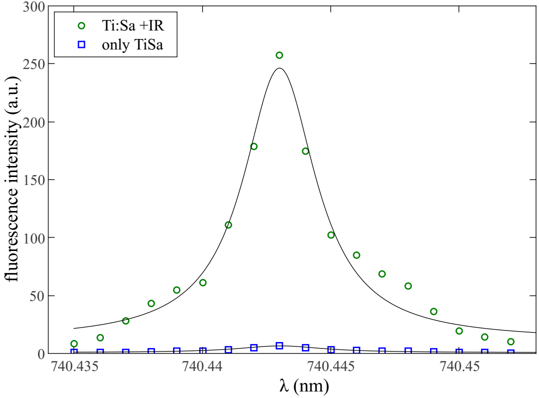
$\delta E \sim 60\,\mathrm{cm}^{-1} \sim 4\,\mathrm{nm}$

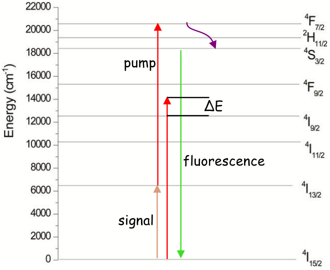
Question

Different width?

other scheme

pump tuned to the $^4F_{7/2}$ level $\rightarrow \sim 20500\,\mathrm{cm}^{-1}$





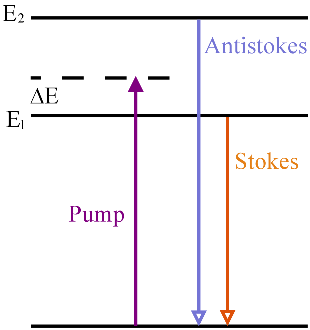
line features

f_c=740.444 nm
$\Gamma \sim 4$ pm
S/N=35
ΔE =750 cm^{-1} $\rightarrow$N$\sim$1.5

N.B: $^4I_{9/2}$=12750 cm^{-1}

pump GSA

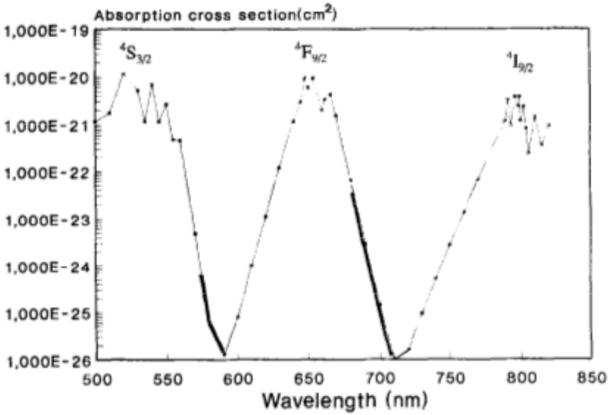
Multiphonon Pump ground state absorption



$$I(E_1 + \Delta E) = I(E_1)exp(-\alpha_{Stokes}\Delta E) + I(E_2)exp(-\alpha_{Antistokes}(E_2 - E_1 - \Delta E))$$
$$\alpha_{Stokes} = (\hbar\omega_m)^{-1}\{ln[N/S_0(n+1)] - 1\} \qquad \alpha_{Antistokes} = \alpha_{Stoke} + 1/k_B T \tag{1}$$

F Auzel, "Multiphonon-assisted anti-stokes and stokes fluorescence of triply ionized rare-earth ions." Physical Review B, *13(7):2809, 1976.*

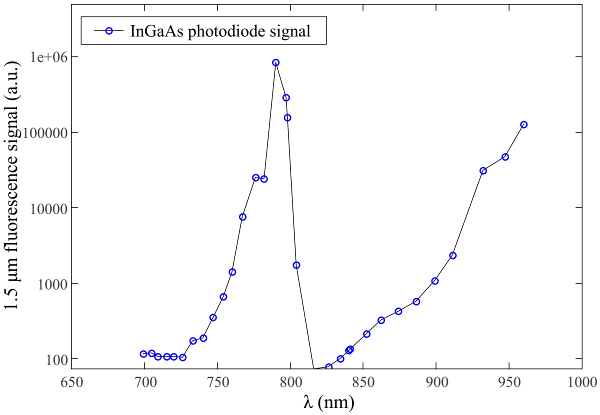
multiphonon absorbtion

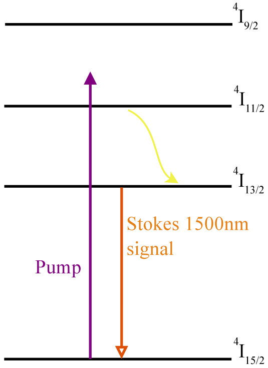


10^6 orders of magnitude!!

Multiphonon absorbtion of Er:YLF at 300 K

multiphonon absorbtion



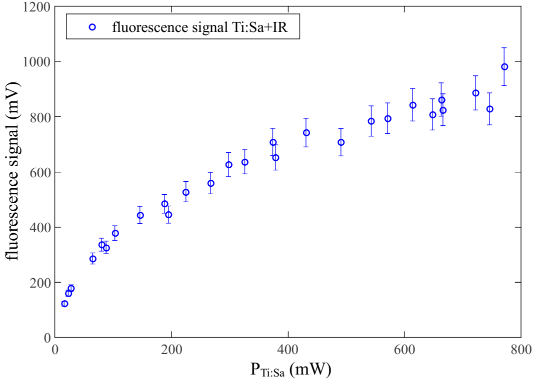


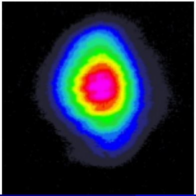
good agreement with Auzel teory!

resonance absorptions

790 nm∼12700 cm^{-1} $\rightarrow^4 I_{9/2}$ multiplet & 960 nm∼10500 cm^{-1} $\rightarrow^4 I_{11/2}$ multiplet

efficiency





beam section

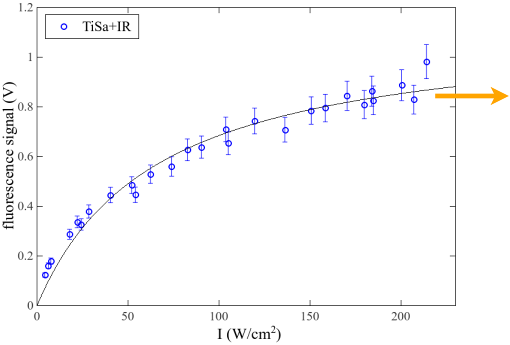
$S=\pi r^2 \sim 1.1 \cdot 10^{-2} cm^2$

efficiency

$$\epsilon_{up} = \frac{N_1(up)}{N_1(up) + N_1(down)} = \frac{N_1\sigma_{12}\frac{I_p}{h\nu_p}}{N_1\sigma_{12}\frac{I_p}{h\nu_p} + \frac{N_1}{\tau_1}} = \frac{1}{1 + \frac{1}{\tau_1\sigma_{12}\frac{I_p}{h\nu_p}}} \quad (2)$$

Consider also recycle mechanism:

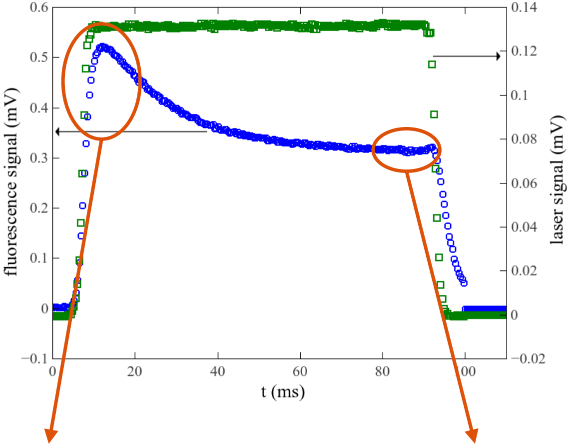
$$\eta_{UC} = \frac{N_v}{N_{IR}^*} = \epsilon_{up}\beta_{20} + \epsilon_{uc}^2\beta_{21}\beta_{20} + \epsilon_{up}^3\beta_{21}^2\beta_{20} + \ldots = \frac{\frac{\beta_{21}}{\beta_{20}}}{\frac{1}{\beta_{21}\epsilon_{uc}} - 1} \quad (3)$$



Max efficiency

η_{UC}@∼800 mW=∼ 70%

laser pulses



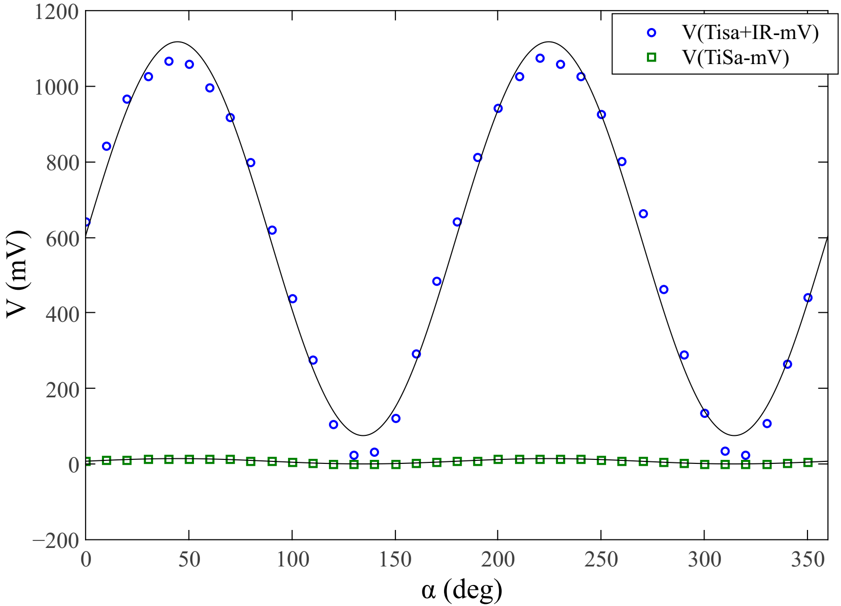
initial situation

$$N_2(initial) = N_0\sigma_{01}\frac{I_s}{h\nu_s}\tau_1 \quad (4)$$

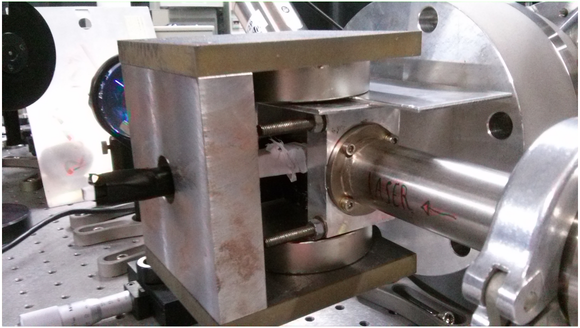
final situation

$$N_2(final) = \frac{N_0\sigma_{23}\frac{I_p}{h\nu_p}\tau_2(1-\frac{1}{1+(\tau_2\alpha)})}{1+\sigma_{23}\frac{I_p}{h\nu_p}\tau_3(1+\frac{\tau_2}{\tau_3(\tau_2\alpha+1)}-\frac{1}{\tau_2\alpha+1})} \quad (5)$$

polarization measurements

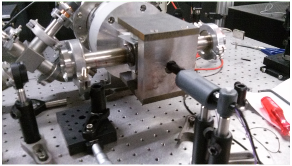


apparatus

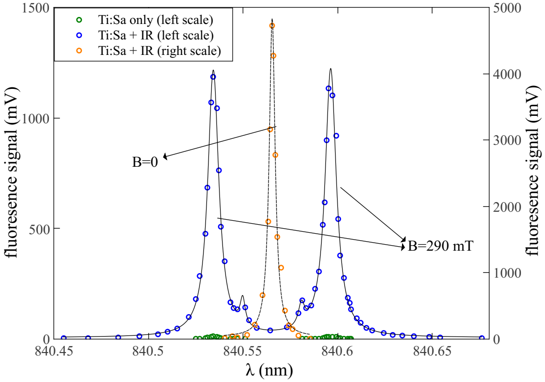


permanent magnet

- gap$\sim$5 cm
- field $\sim$280 mT



Zeeman splitting



questions

- too much symmetry?
- linewidth?

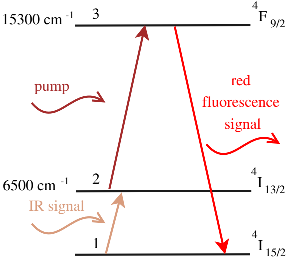
Zeeman effect

$$\left.\begin{array}{l}\delta E = \mu_b \cdot \mathrm{B} \\ \mathrm{B}{=}290\,\mathrm{mT}\end{array}\right\} \rightarrow \sim 6\,\mathrm{GHz\ splitting}$$

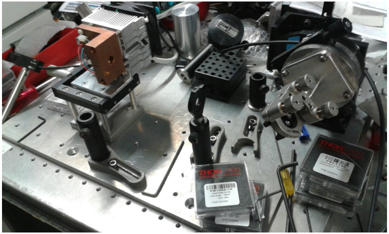
In Er:YLF

To do

- low energy photon pump $\rightarrow \sim 1170\,\text{nm}$
- low doping concentration (0.01%)



New gain chip laser Innolume



the end

Thanks for your attention