AXIOMA experiment

New measurements: crystal choice

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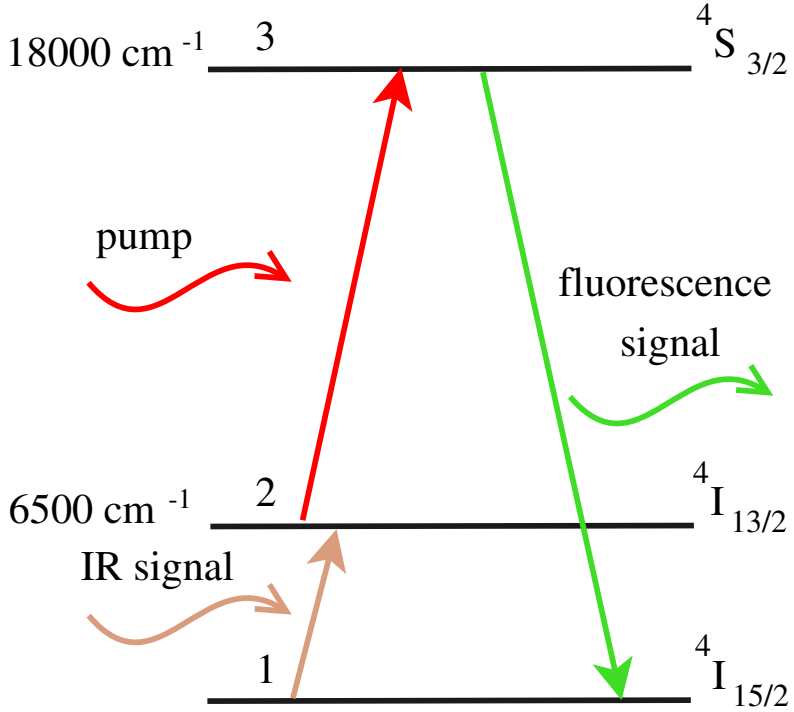
general idea

IRQC scheme in Er^{3+}

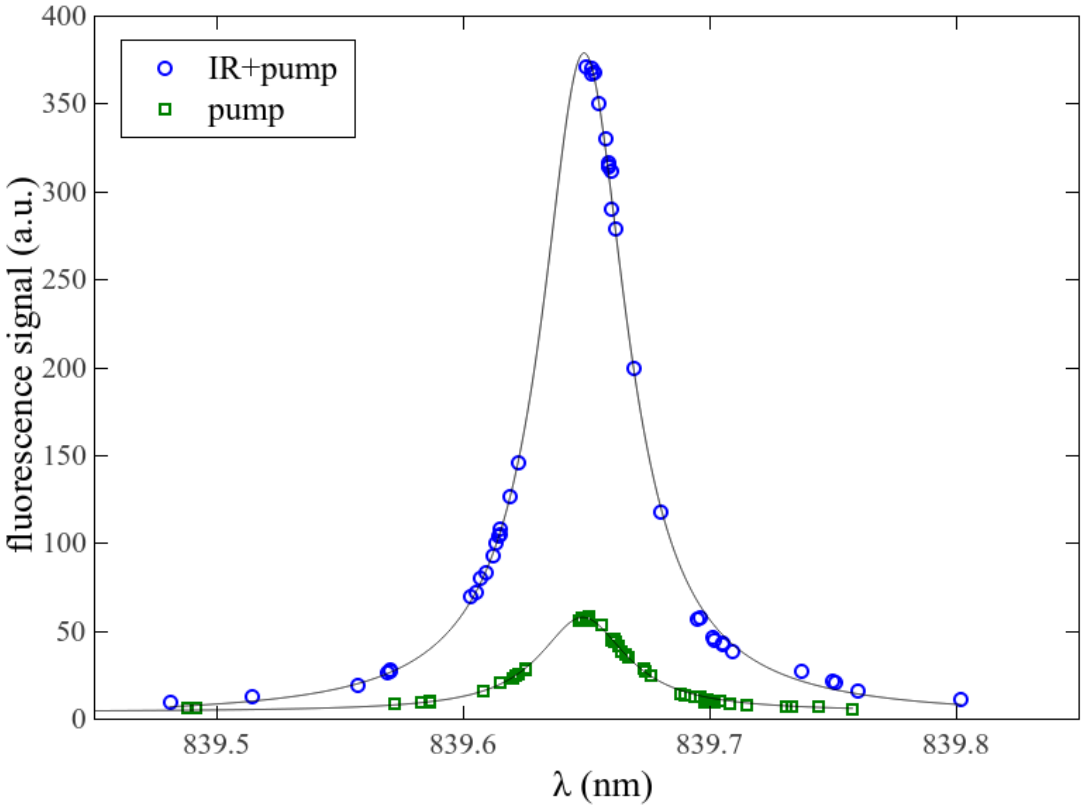


properties in YAG

- GSA absorption in 1450 ± 50 nm band;
- $\sim$10 ms lifetime of $^4I_{13/2}$;
- pump wavelength $\sim$839 nm;

past result

Infrared quantum counter with Er^{3+}:YAG doped at 0.5%

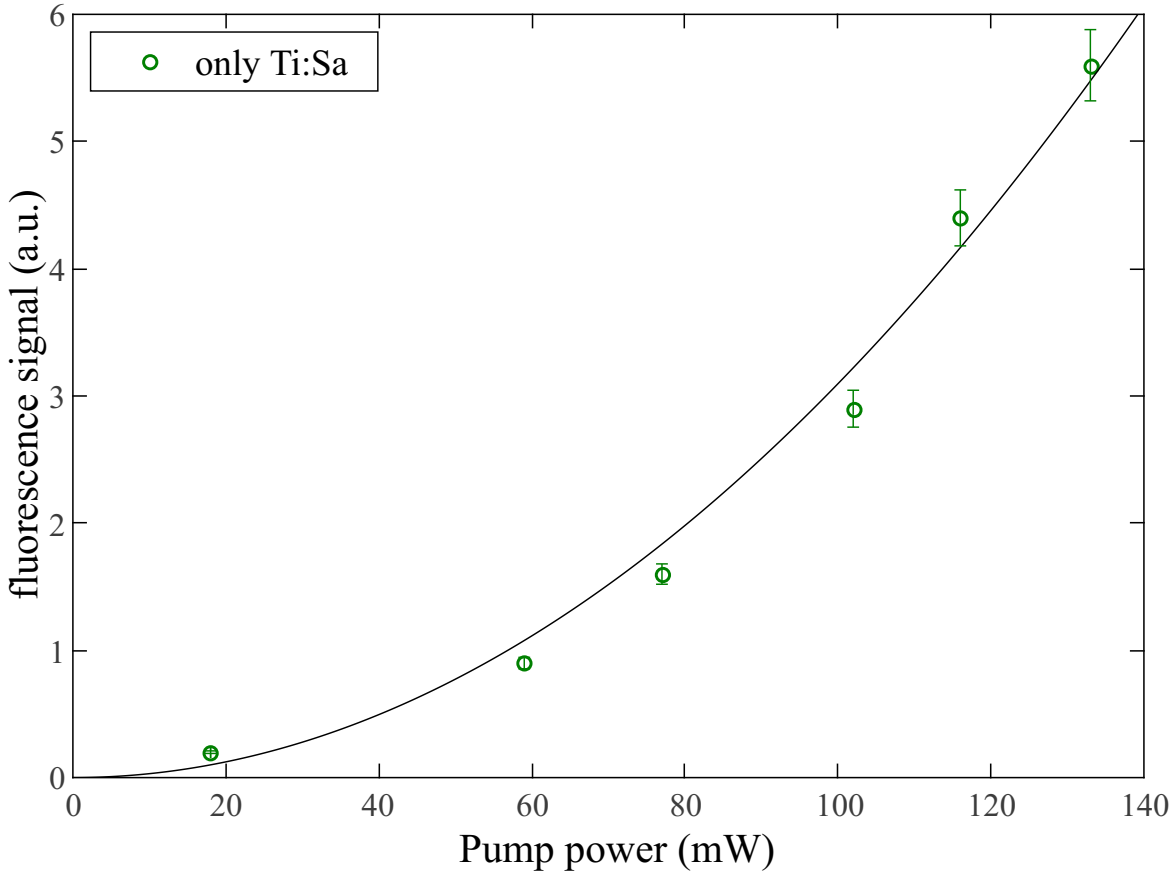


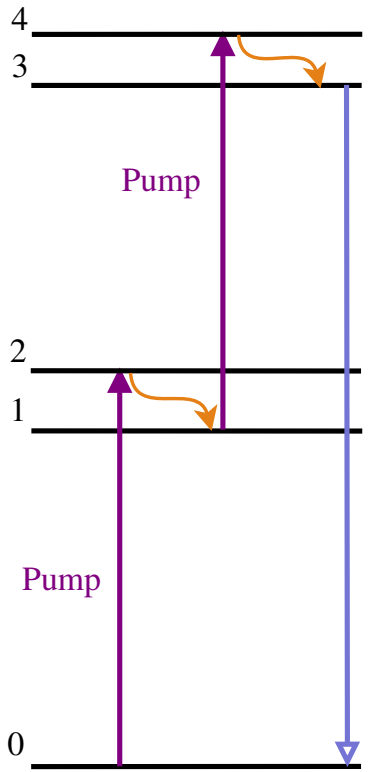
results

- 540 nm fluorescence signal far from pump wavelength (839 nm);
- $\sim 2-3\%$ up-conversion efficiency;
- S/N$\sim$ 12;

Background fluorescence signal in coincidence with only pump flux!

background fluorescence





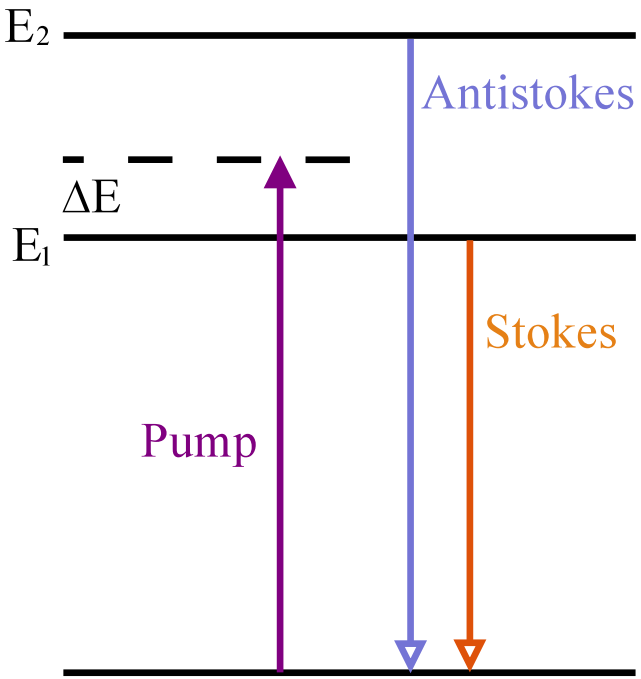
Two photons absorption:

$$N_3 \propto \frac{\frac{\sigma_{02} I}{h\nu}^2 \sigma_{02}\sigma_{14}}{\sigma_{12}\frac{\sigma_{02} I}{h\nu} + \frac{1}{\tau_1}} \propto P_{Ti:Sa}^2 \qquad (1)$$

if $\frac{\sigma_{02} I}{h\nu} << \frac{1}{\tau_1}$

pump GSA

Multiphonon Pump ground state absorption

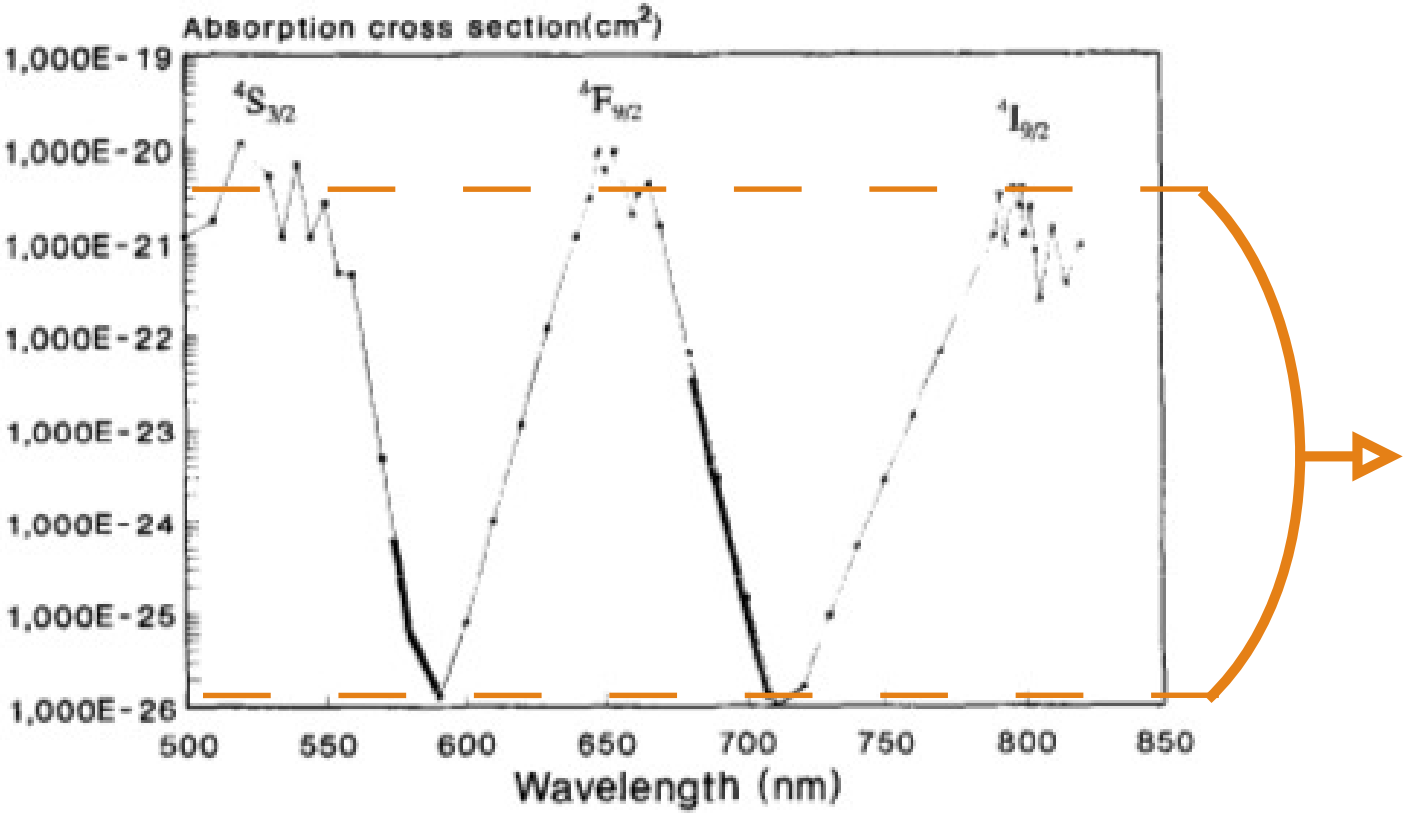


$$I(E_1+\Delta E) = I(E_1)exp(-\alpha_{Stokes}\Delta E) + I(E_2)exp(-\alpha_{Antistokes}(E_2-E_1-\Delta E)) \quad (2)$$

$$\alpha_{Stokes} = (\hbar\omega_m)^{-1}\{ln[N/S_0(n+1)]-1\} \qquad \alpha_{Antistokes} = \alpha_{Stoke} + 1/k_B T$$

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 77 K

wishes

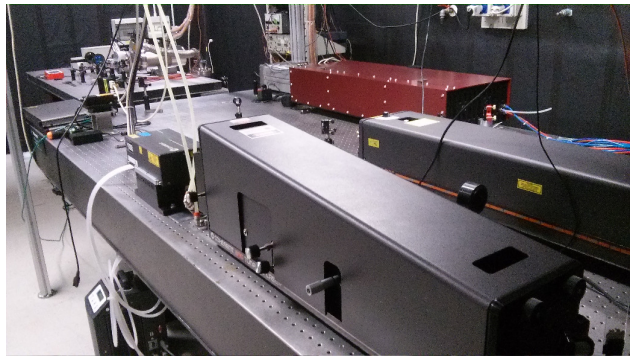
$$\left.\begin{array}{l}\text{high } \Delta E \\ \text{low } E_{phonon}\end{array}\right\} \rightarrow \text{high N}$$

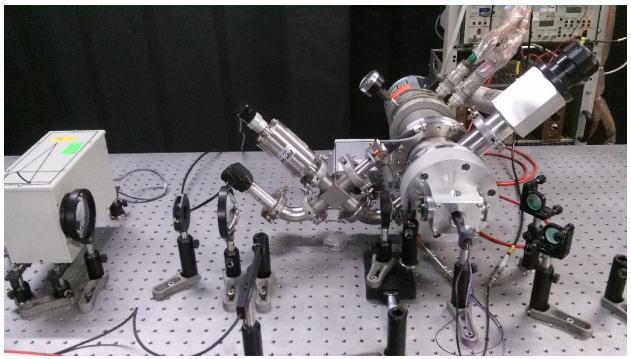
optically pure crystals

matrix	conduction band energy (eV)	phonon energy (cm^{-1})
YAG	~ 7.9	~ 800
YLF	~ 10.5	~ 500
KPB	~ 4.12	~ 140
LaF_3	$\sim 8.8 - 10.3$	~ 350
KYF	~ 6	~ 400
BYF	~ 7.5	~ 370

Table: Principal properties of some matrices.

set-up



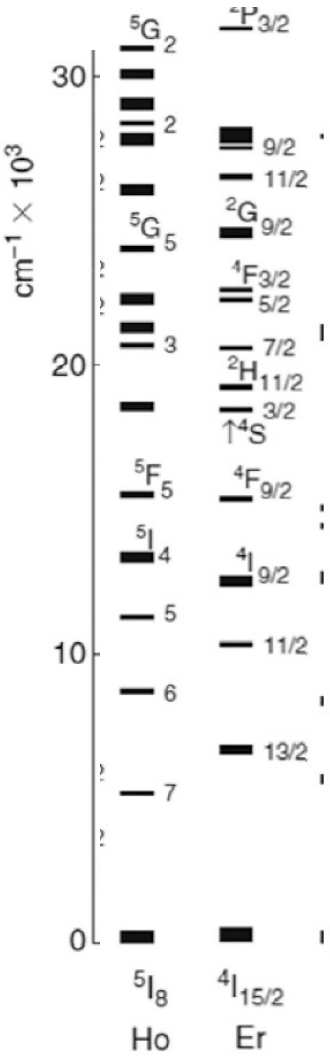


features

- 10 K cryocooler;
- IR source (power$\sim$ 1 mW/nm);
- Ti:Sa laser $\rightarrow$ wavelength range 780-880 nm;
- DYE laser $\rightarrow$ wavelength range 575-615 nm;

crystals

- Er^{3+} in KYF(at 1%) & YLF(at 1%) (besides YAG (at 0.5%);
- Ho^{3+} in YLF(at 0.8%);

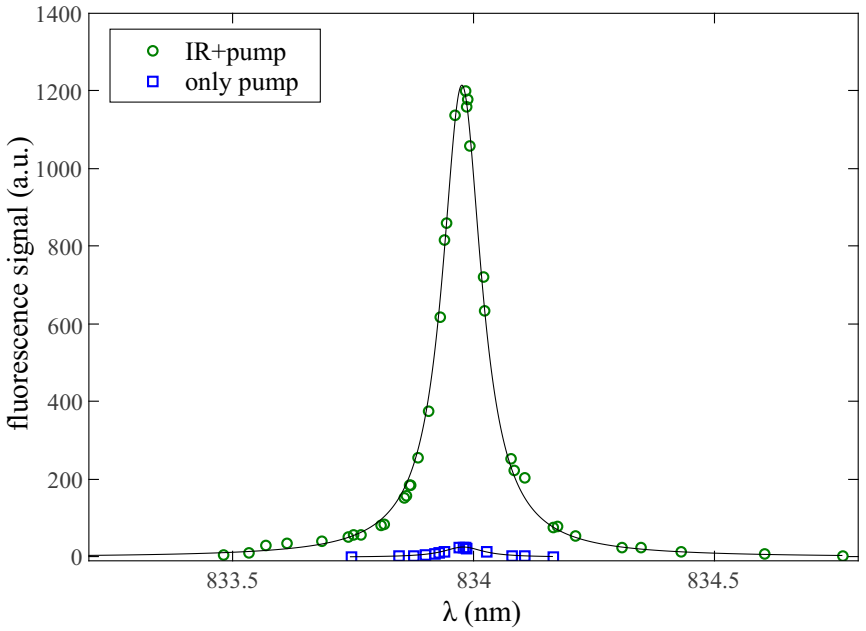


IRQC schemes:

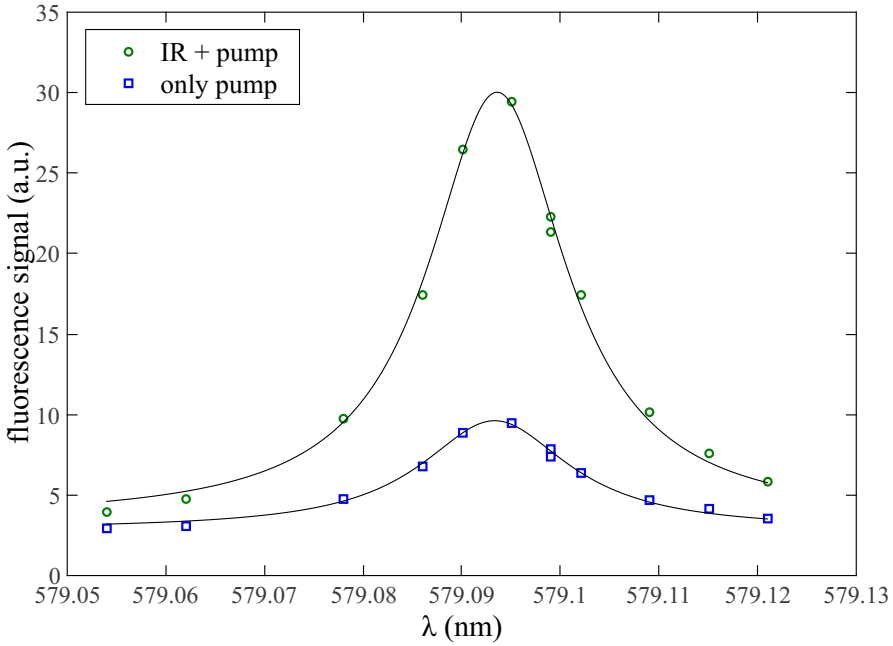
- Er^{3+}: IR in 1500 nm band + pump at ∼840 nm → fluorescence in 550 nm band;
- Er^{3+}: IR in 1000 nm band + pump at ∼579 nm → fluorescence in 550 nm band;
- Ho^{3+}: IR in 2000 nm band + pump at ∼580 nm → fluorescence in 545 nm band;
- Ho^{3+}: IR in 2000 nm band + pump at ∼780 nm → fluorescence in 545 nm band;

Er^{3+}:KYF

Ti:Sa pump



DYE pump



characteristics

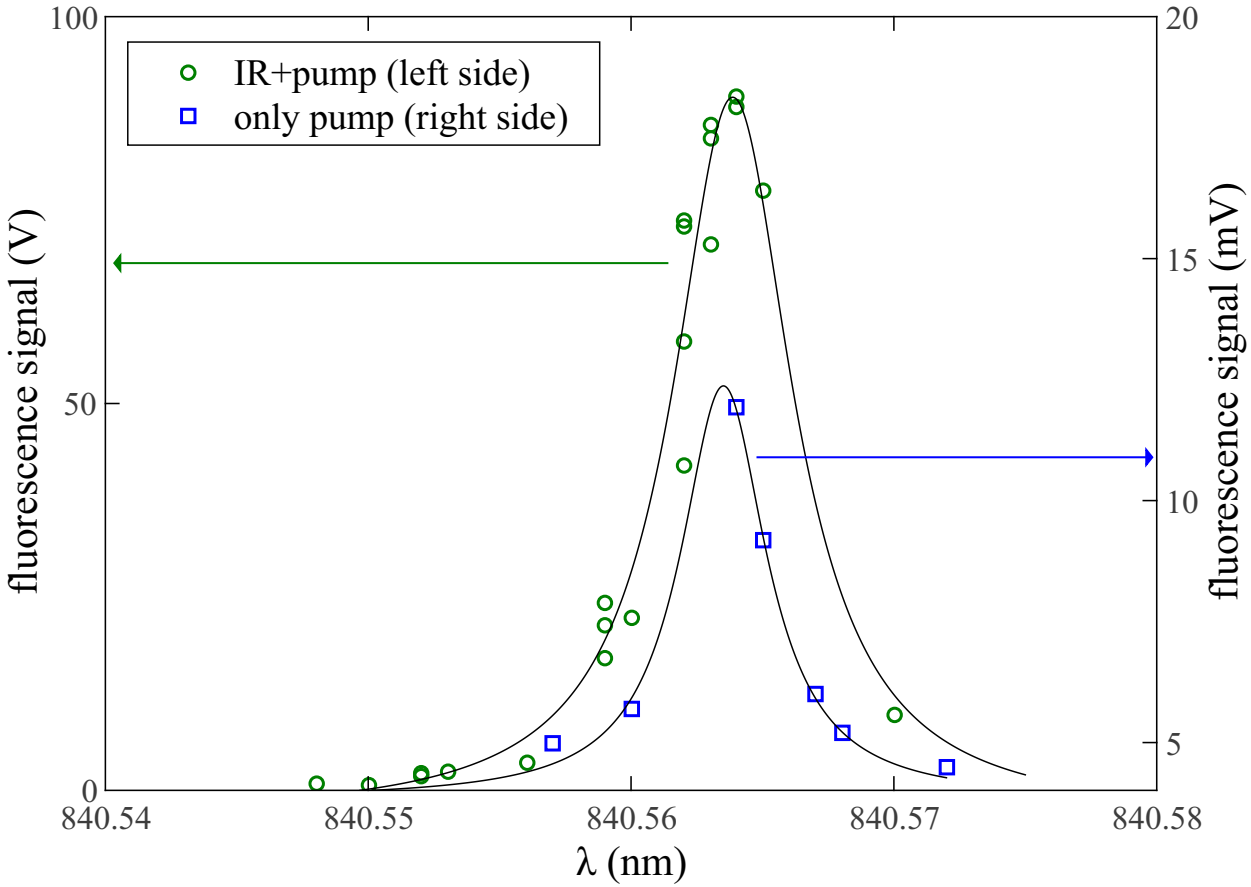
- linewidth$\sim$ 10 pm;
- S/N $\sim$ 200;
- ΔE $\sim$1500 cm^{-1} $\rightarrow$ N$\sim$ 4;

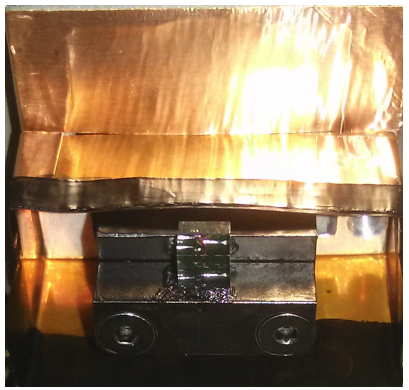
characteristics

- linewidth$\sim$ 17 pm;
- S/N $\sim$3;
- ΔE $\sim$ 1750 cm^{-1} $\rightarrow$ N$\sim$ 4.5;

PROBLEM: disorderly crystal!!

Er^{3+}:YLF



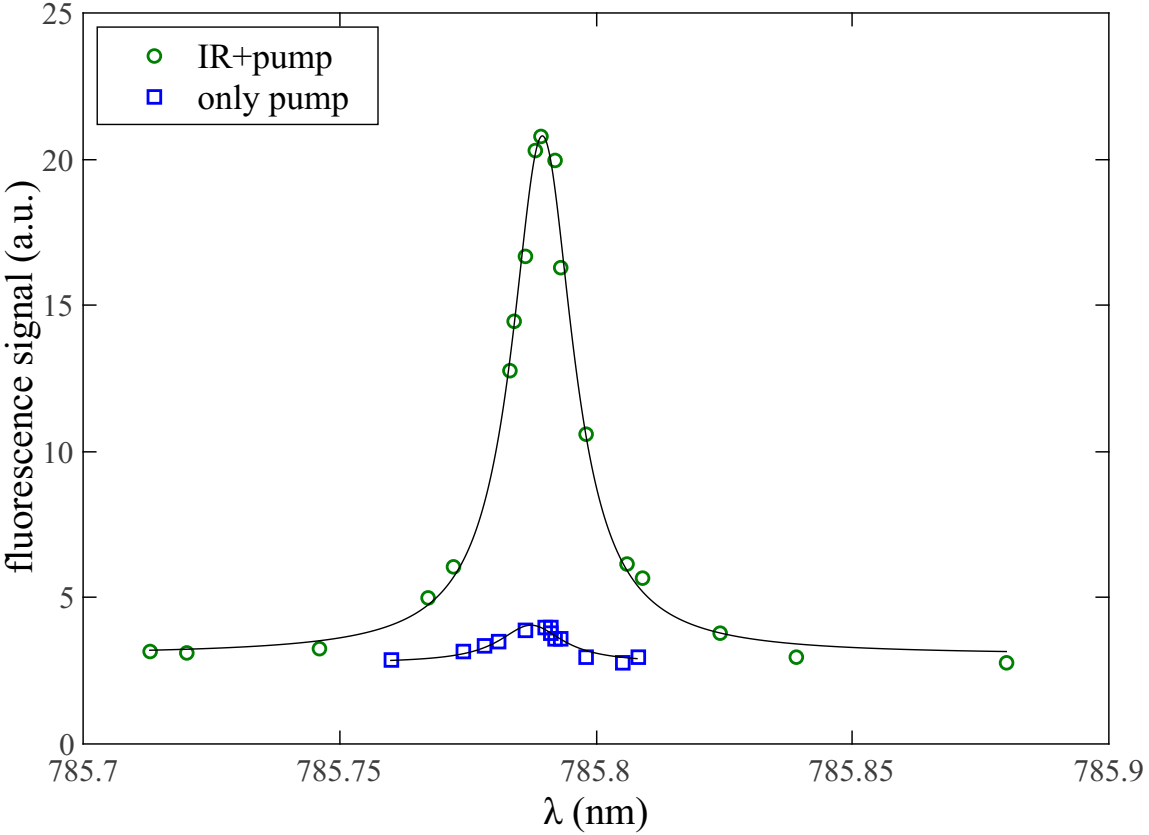


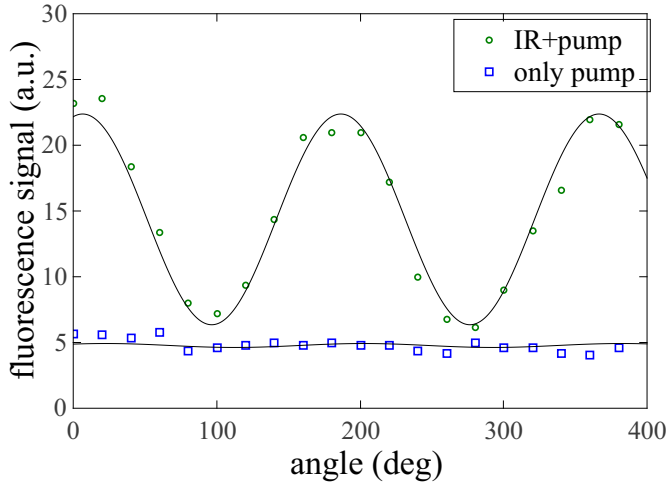
features

- pump flux $\sim 10\,\mathrm{W/cm^2}$;
- S/N$\sim$5000;
- linewidth$\sim$ 4 *pm*;

$$\left.\begin{array}{r} \Delta E \sim 1500\,\mathrm{cm}^{-1} \\ E_{phonon} \sim 500\,\mathrm{cm}^{-1} \end{array}\right\} \rightarrow N \sim 3$$

Ho^{3+}:YLF





features

- pump flux $\sim 0.5\,W/cm^2$;
- S/N$\sim$30;
- linewidth$\sim$ 15 *pm*;
- pump polarization dependent;

Tm and Nd

Tm:BYF

- IR in the 2 μm band;
- pump at 638 nm;
- fluorescence in the 480 nm band;

Nd:BYF

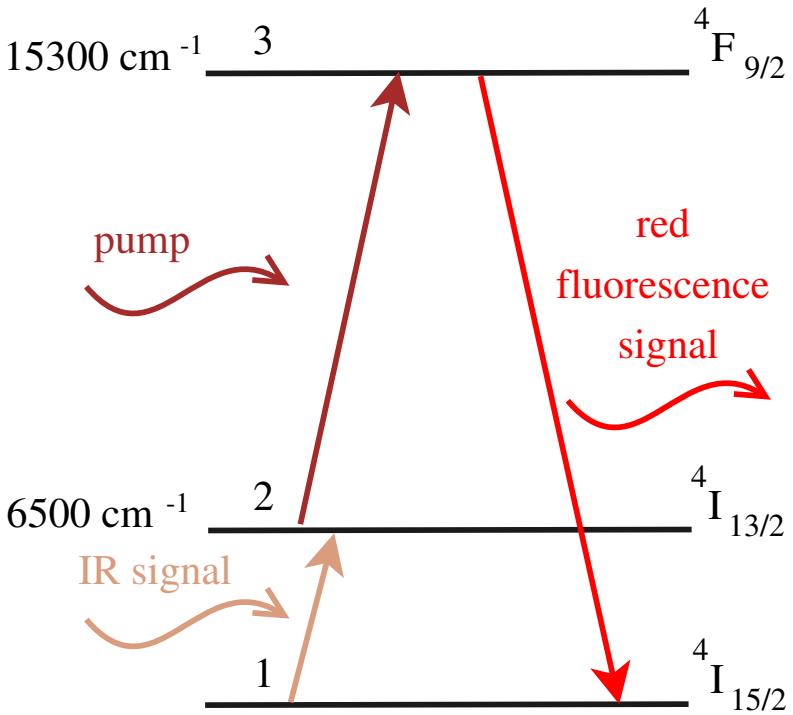
- IR in the 1 μm band;
- pump at 604 nm;
- fluorescence in the 480 nm band;

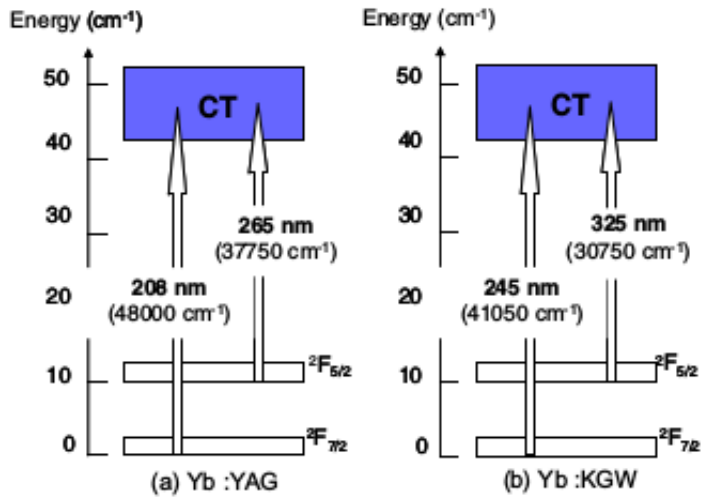
... to be implemented at 10 K!!

IRQC detectors

crystals

- Er^{3+} in other matrix (especially in low phonon crystals);
- crystals doped at different concentrations;
- Dy^{3+} in fluoride crystals;
- Yb^{3+} in sulfide crystals;

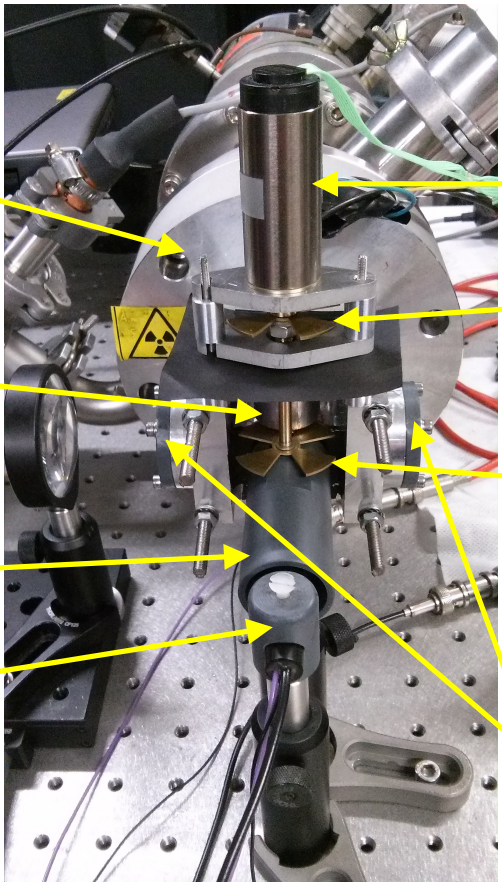




pump schemes

- pump wavelength in the 690-780 nm and 890-1000 nm bands;
- low energy photon pump (1170 nm in Er^{3+});

γ ray detection



system

- source γ source$\rightarrow 10^7 \gamma$/ s ste;
- chopper $\rightarrow$ lock-in detection;

the end

Thanks for your attention