Er^{3+}:YAG IRQC at 10K

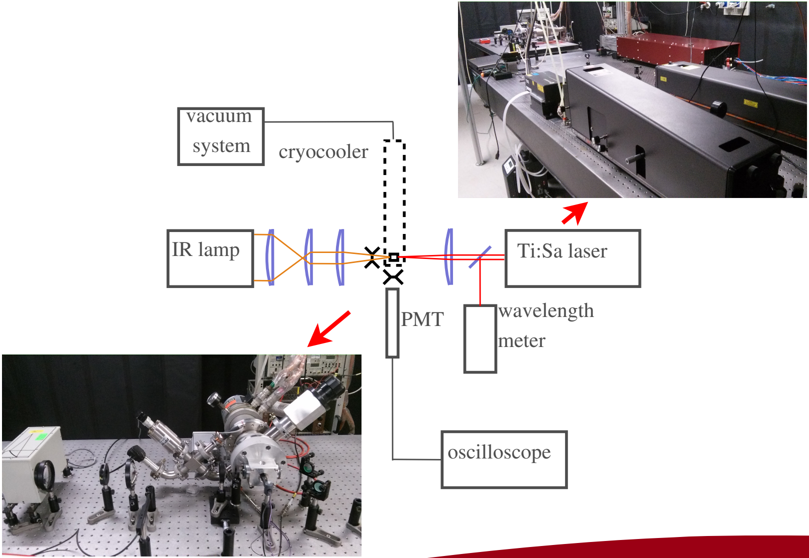
January 28, 2016

Introduction

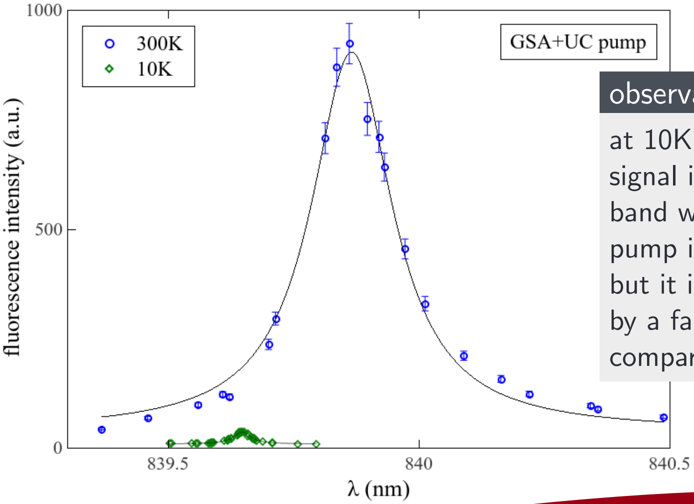
Er^{3+}(0.5%):YAG at 10K.......

1. ...... pump noise???
2. ...... infrared quantum counter???

Experimental set-up



pump GSA and upconversion



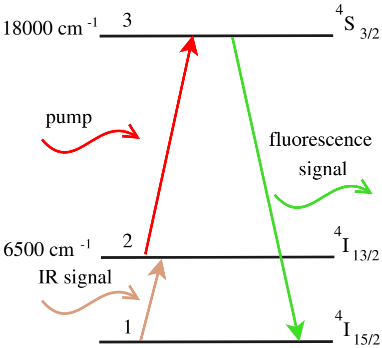
observation

at 10K fluorescence signal in 550 nm band with only the pump is still there! but it is suppressed by a factor ~ 20 compared to 300 K!

P_{pump} ~100 mW

Er^{3+}:YAG counter for $\sim$1.45 μm photons

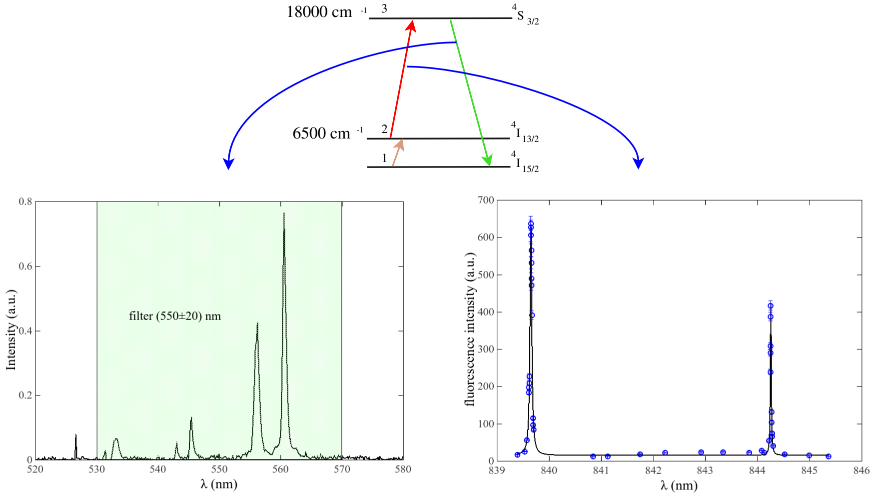
Er^{3+} energy level scheme



properties

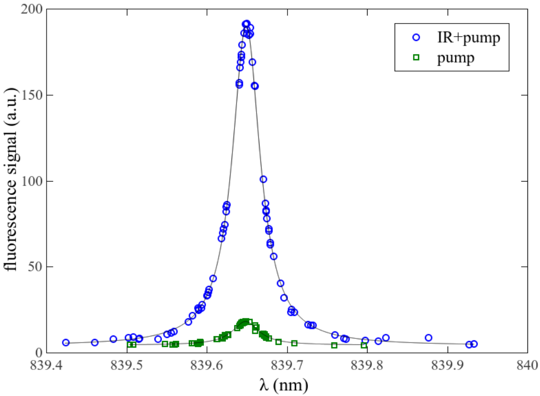
- GSA absorption in 1450 ± 50 nm band;
- $\sim$10 ms lifetime of $^4I_{13/2}$;
- pump wavelength $\sim$839 nm;

Fluorescence signal in the 550 nm band



PMT efficiency at 550 nm=10%

Fluorescence signal in the 550 nm band



features

- linewidth∼40 pm (compared to ∼ 200 pm at 300 K);
- S/N∼12
- wavelength peak at (839.649 nm

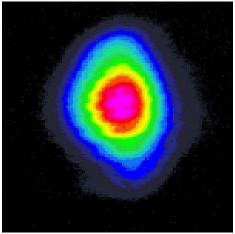
Evaluation of η_{UC}

Upconversion efficiency

$$\eta_{UC} = \frac{\text{number of fluorescence photons}}{\text{number of IR photons absorbed}} = \eta_f \tau_2 \sigma_{23} n_{pump} \quad (1)$$

where:

- η_f is the radiative efficiency of $^4S_{3/2} \sim 1$;
- τ_2 is the radiative lifetime of $^4I_{13/2}$ level $\sim 10\,\text{ms}$;
- σ_{23} is the ESA cross section $^4I_{13/2} \rightarrow ^4S_{3/2} \sim 5 \cdot 10^{-20} cm^2$;
- n_{pump} is the pump photon flux;



Er^{3+}(0.5%):YAG, $n_{pump} \sim 6\,\text{W/cm}^2 \rightarrow \eta_{UC} \sim 2.5\%$

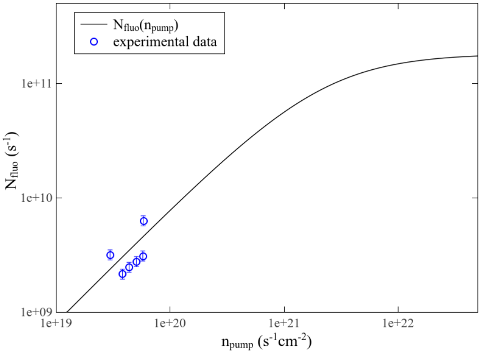
steady-state equation

$$N_{fluo}(n_{pump}) = \frac{N^{Er^{3+}} \sigma_{23} n_{pump} (1 - \frac{1}{1+(\tau_2 \alpha)})}{1 + \sigma_{23} n_{pump} \tau_3 (1 + \frac{\tau_2}{\tau_3(\tau_2\alpha+1)} - \frac{1}{\tau_2\alpha+1})} \left[\frac{ph}{s}\right] \quad (2)$$

where:

- $N^{Er^{3+}}$ is the erbium atoms in the Ti:Sa volume;
- σ_{23} is the ESA cross section between level $^4I_{13/2}$ and $^4S_{3/2}$;
- τ_2 is the radiative lifetime of $^4I_{13/2}$ level;
- $\alpha = n_{IR} \int \sigma_{12}(\lambda) d\lambda$, with σ_{12} is the GSA cross section between level $^4I_{13/2}$ and $^4I_{15/2}$;
- τ_3 is the radiative lifetime of $^4S_{3/2}$ level

steady state equation



experimental data

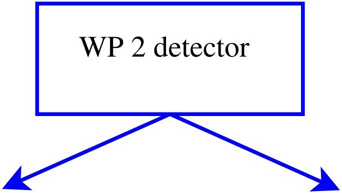
$$N_{fluo} = \frac{i_{PMT}}{G \epsilon q_e \frac{d\Omega}{\Omega} T_f} \quad (3)$$

max UC efficiency

2%$< \eta_{UC} <$5%

- $N^{Er^{3+}} = \rho^{Er^{3+}} \cdot V = 2.3 \cdot 10^{19}\,\mathrm{cm}^{-3} x 3.9 \cdot 10^{-3}\,\mathrm{cm}^3 = 9 \cdot 10^{16}$
- $\sigma_{23} = 5 \cdot 10^{-20}\,\mathrm{cm}^2$
- $\alpha = n_{IR} \int \sigma_{12}(\lambda) d\lambda = 1.25 \cdot 10^{11} x 1.6 \cdot 10^{-17} = 2 \cdot 10^{-6}\,\mathrm{s}^{-1}$

experimental procedure for future



IRQC scheme

- no pump GSA;
- highη_{UC} (high cross section, low phonon energy, ..);
- simple geometry
- ......

scintillator scheme

- high IR light yield;
- ......