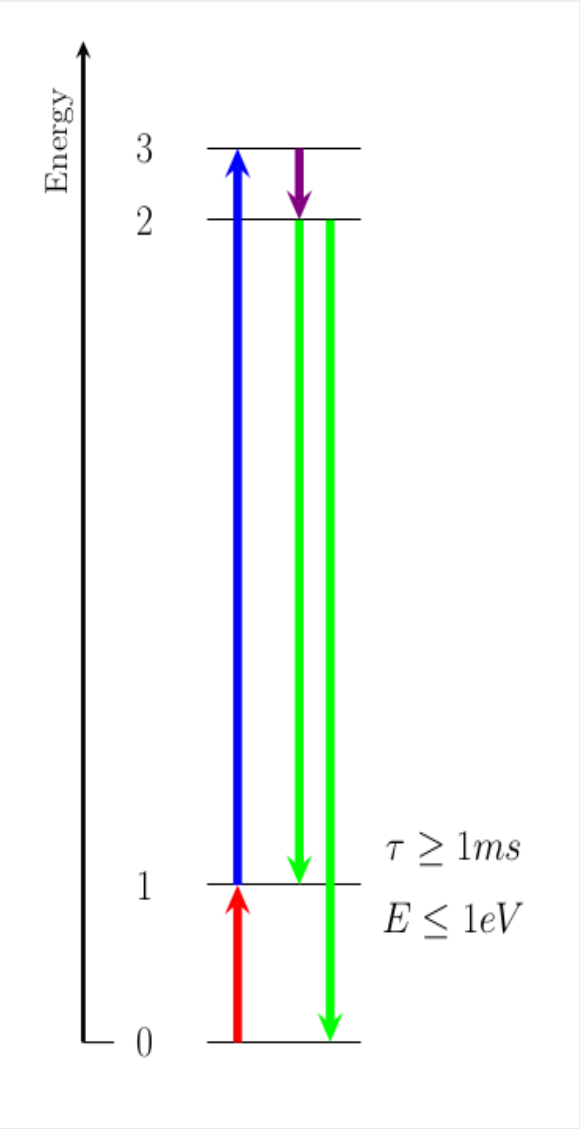
Laser amplified scintillations and axion dark matter research

Padova, 20 Giugno 2017

Basic idea



Legend:

Excitation due to particle passage

cw tuned laser pump

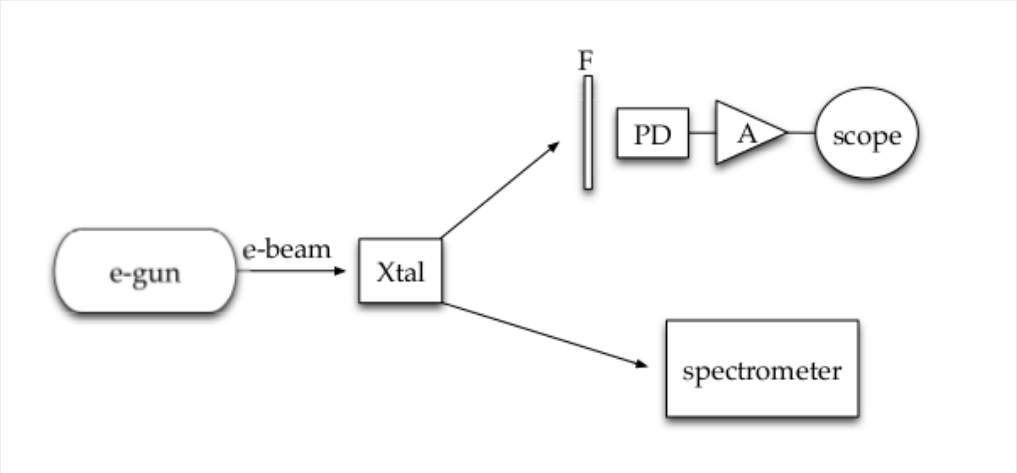
non radiative transition

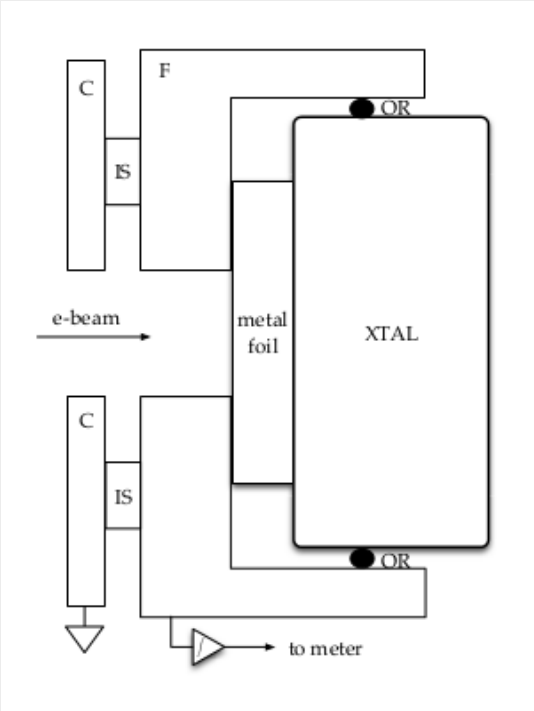
visible luminescence

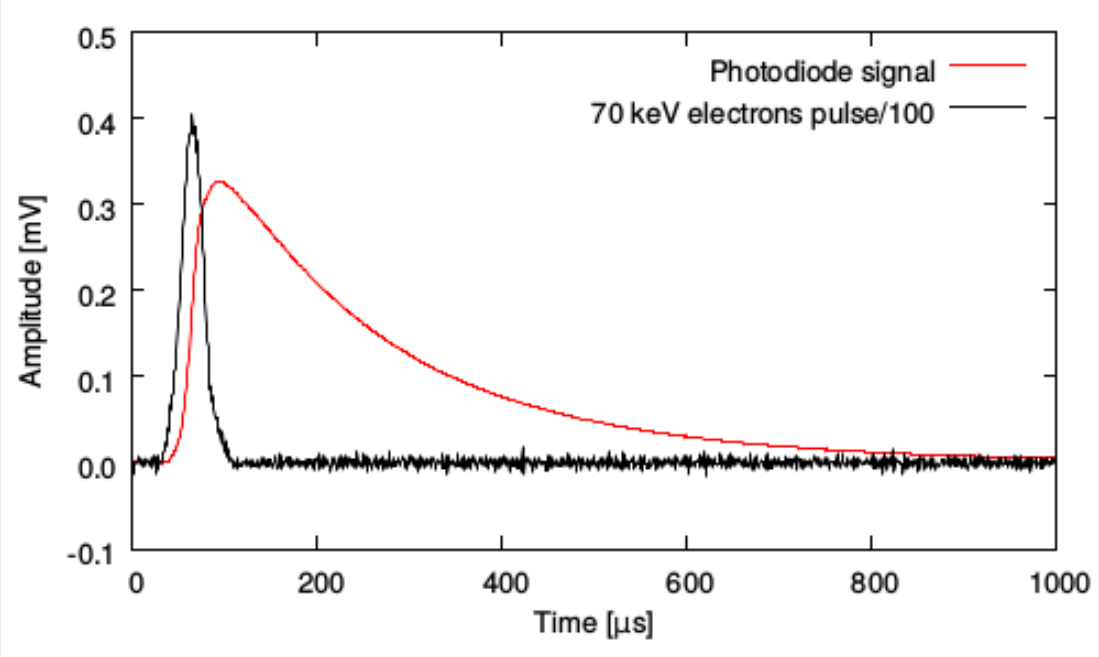
Requirements:

- high production of excited ions in the lowest metastable due to the particle passage
- high upconversion efficiency
- high trasparency to laser radiation of rare-earth ions in the groundstate

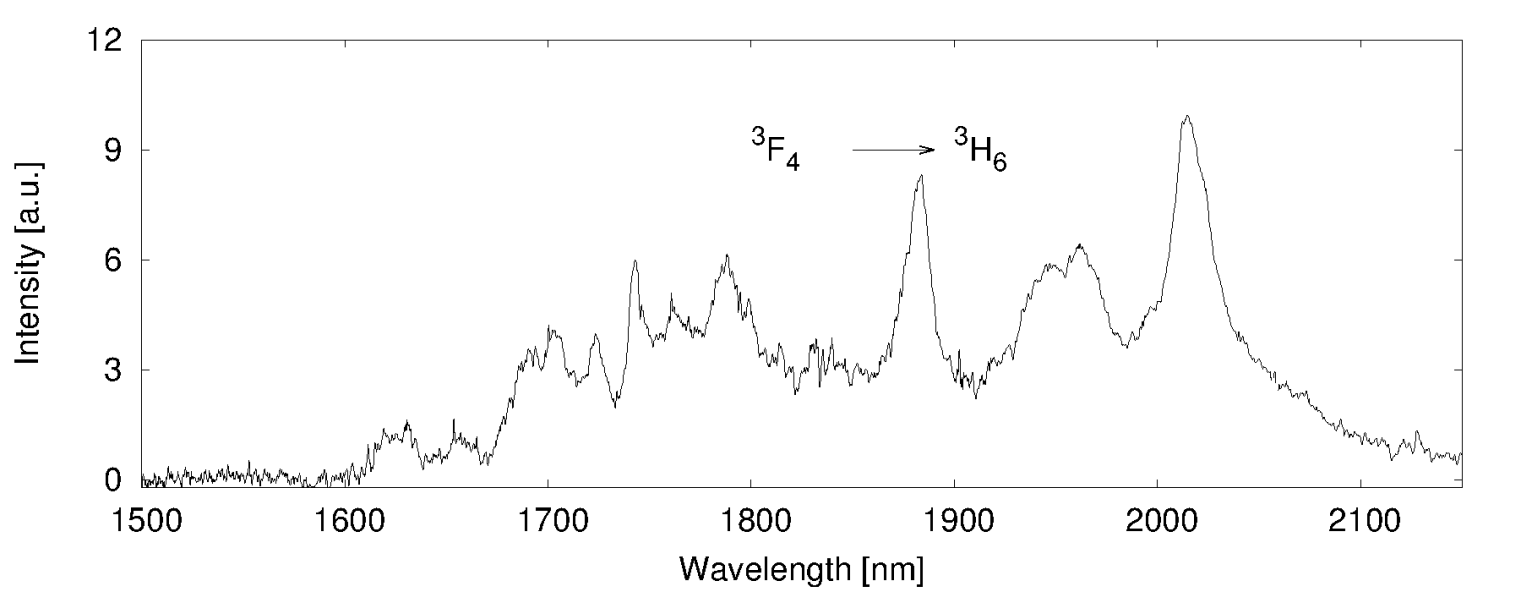
Broadband cathodo- and radioluminescence studies

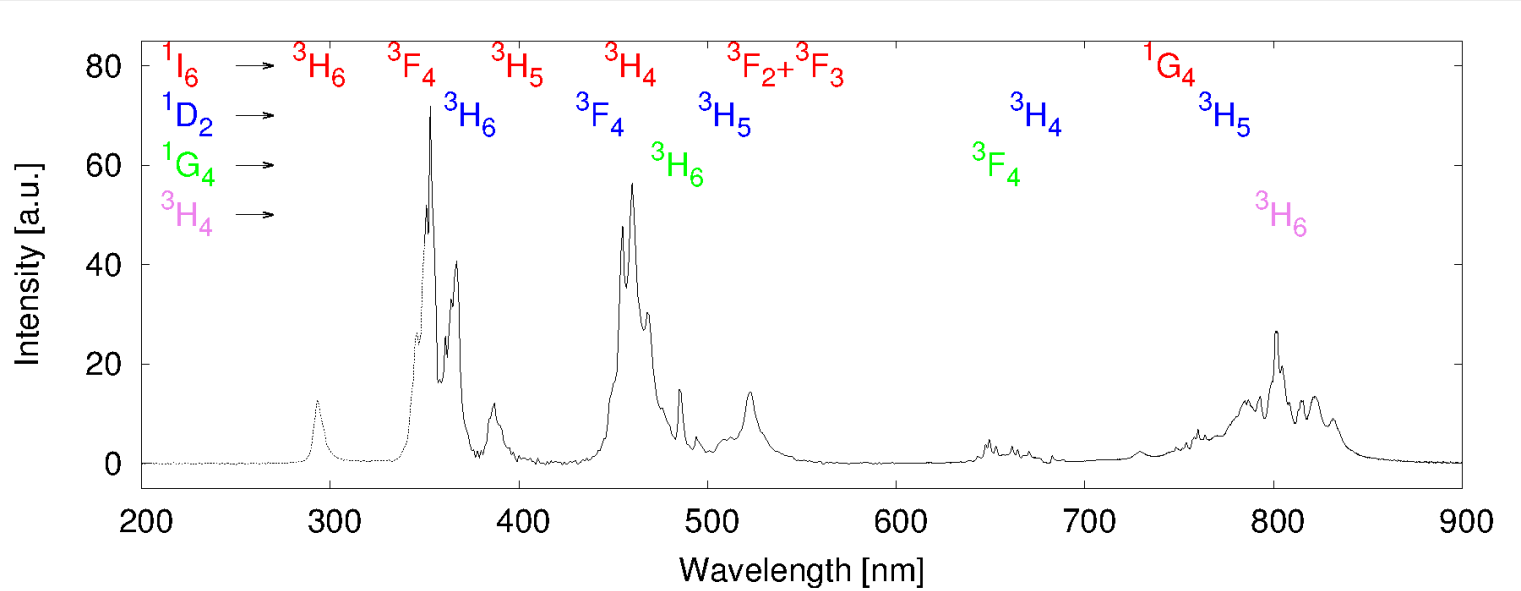




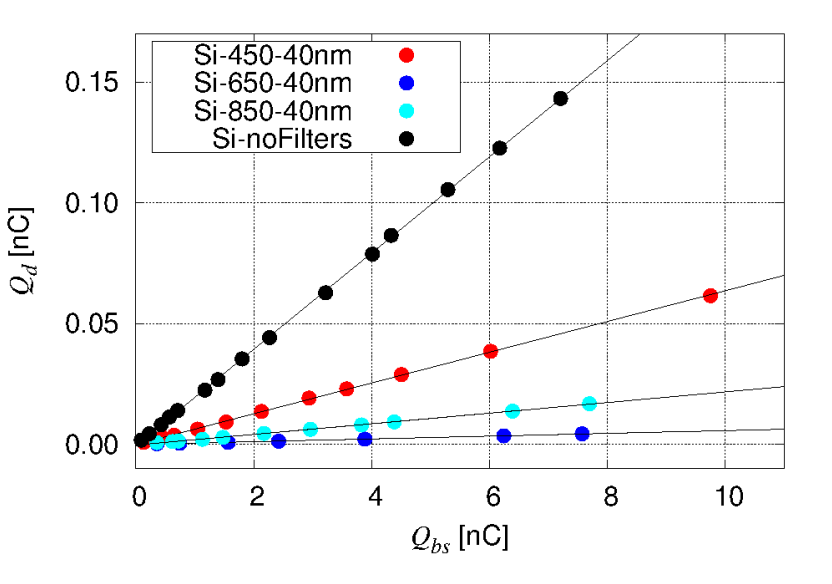


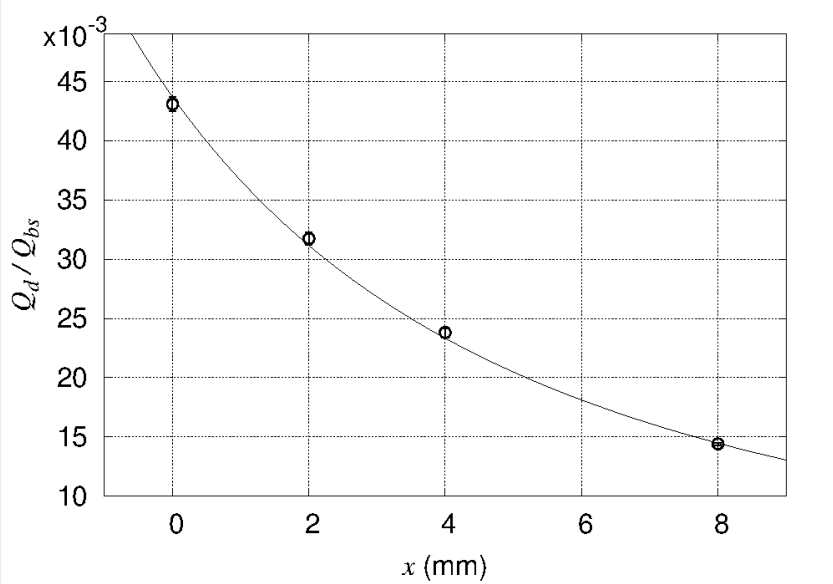
Broadband cathodo- and radioluminescence studies

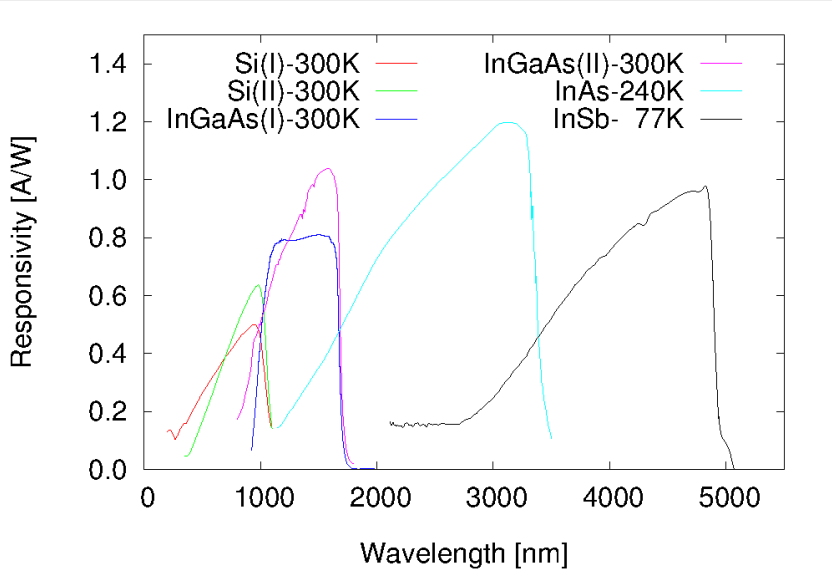


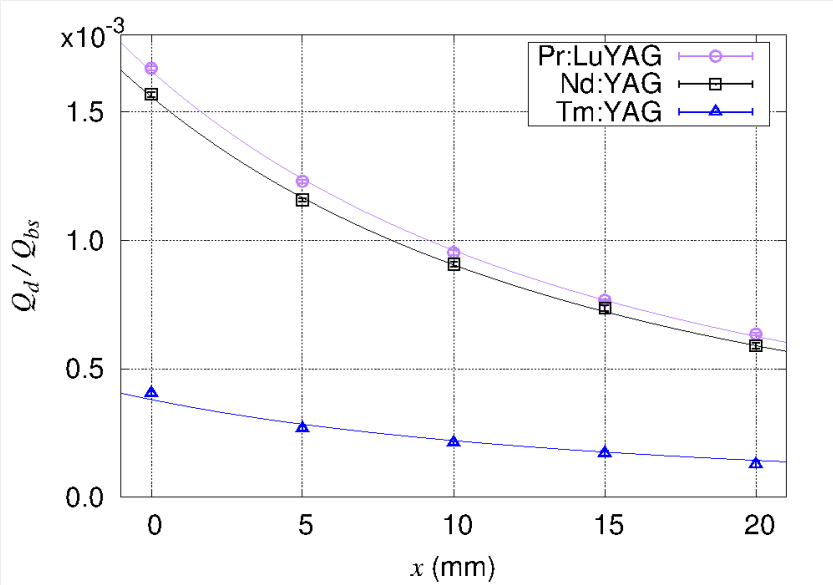


Broadband cathodo- and radioluminescence studies

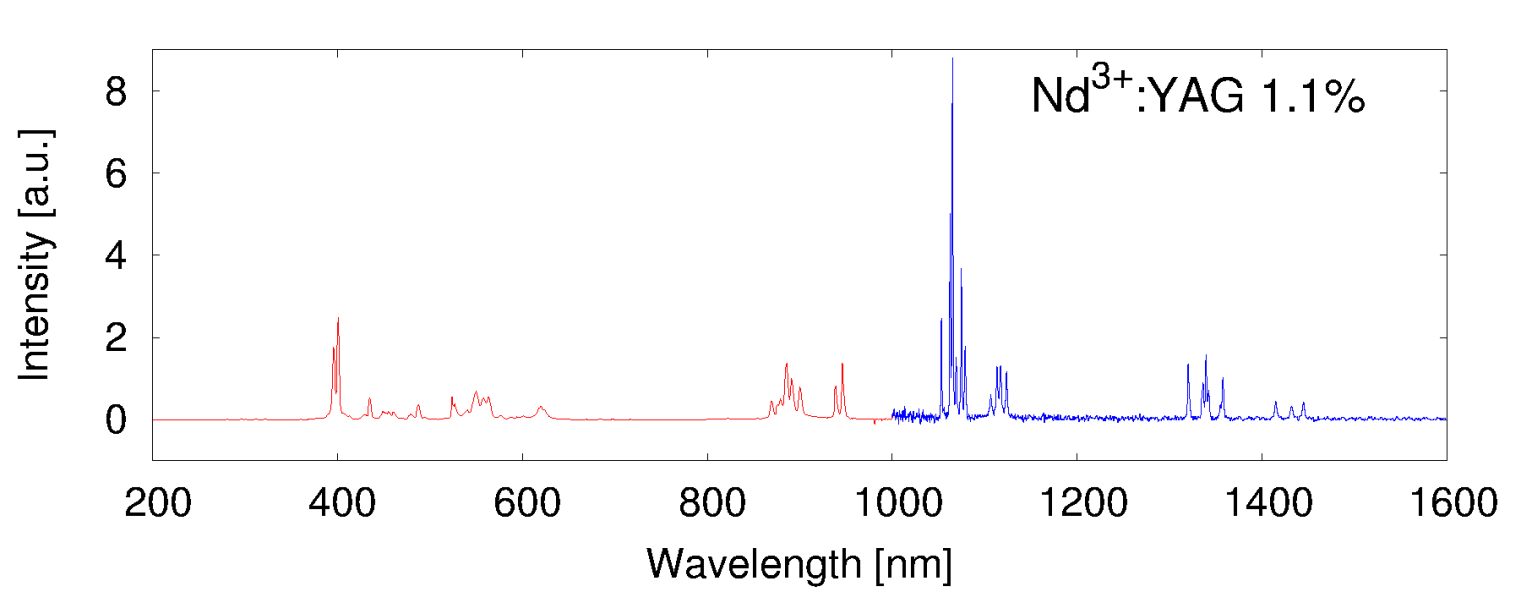


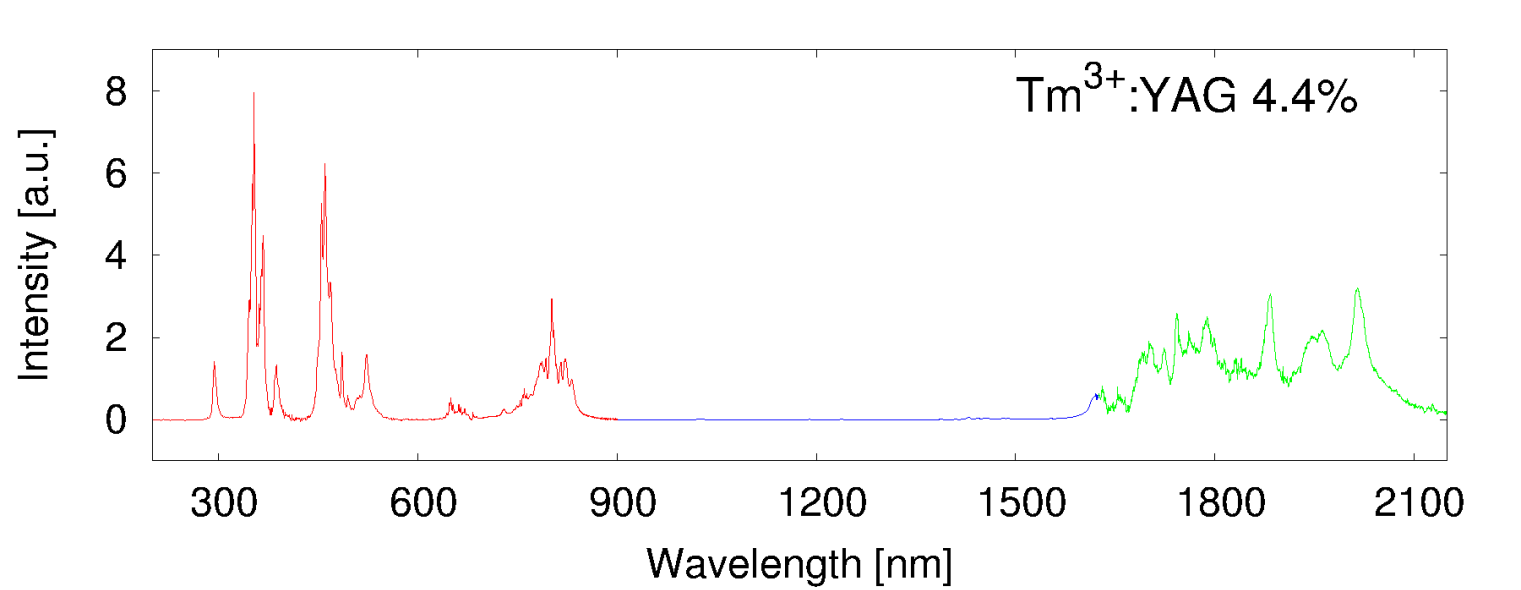




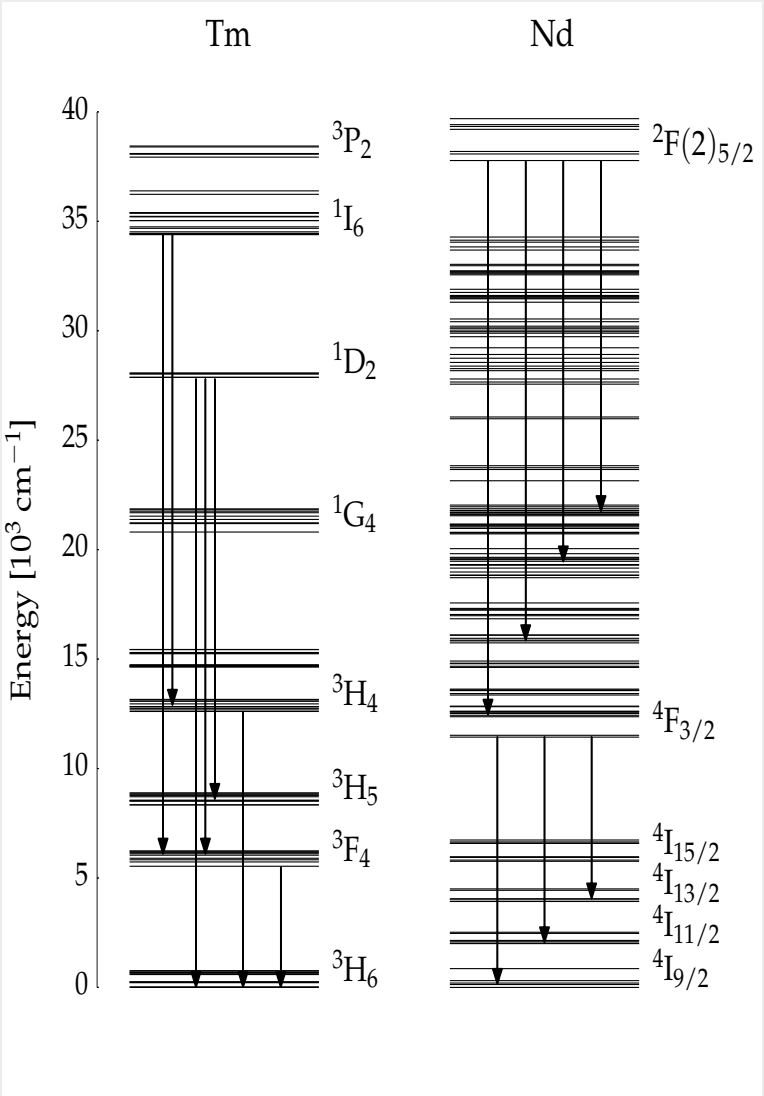


Broadband cathodoluminescence spectra





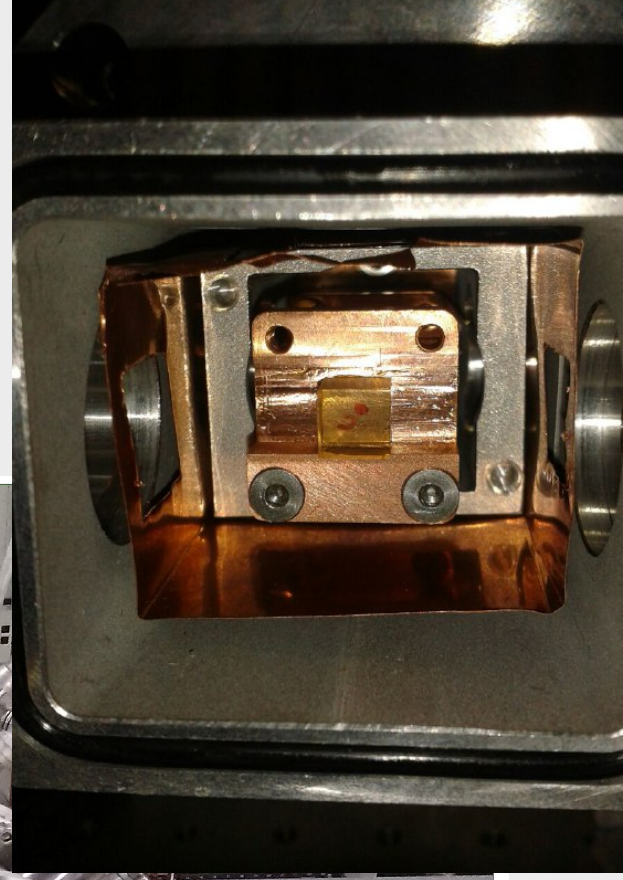
Results

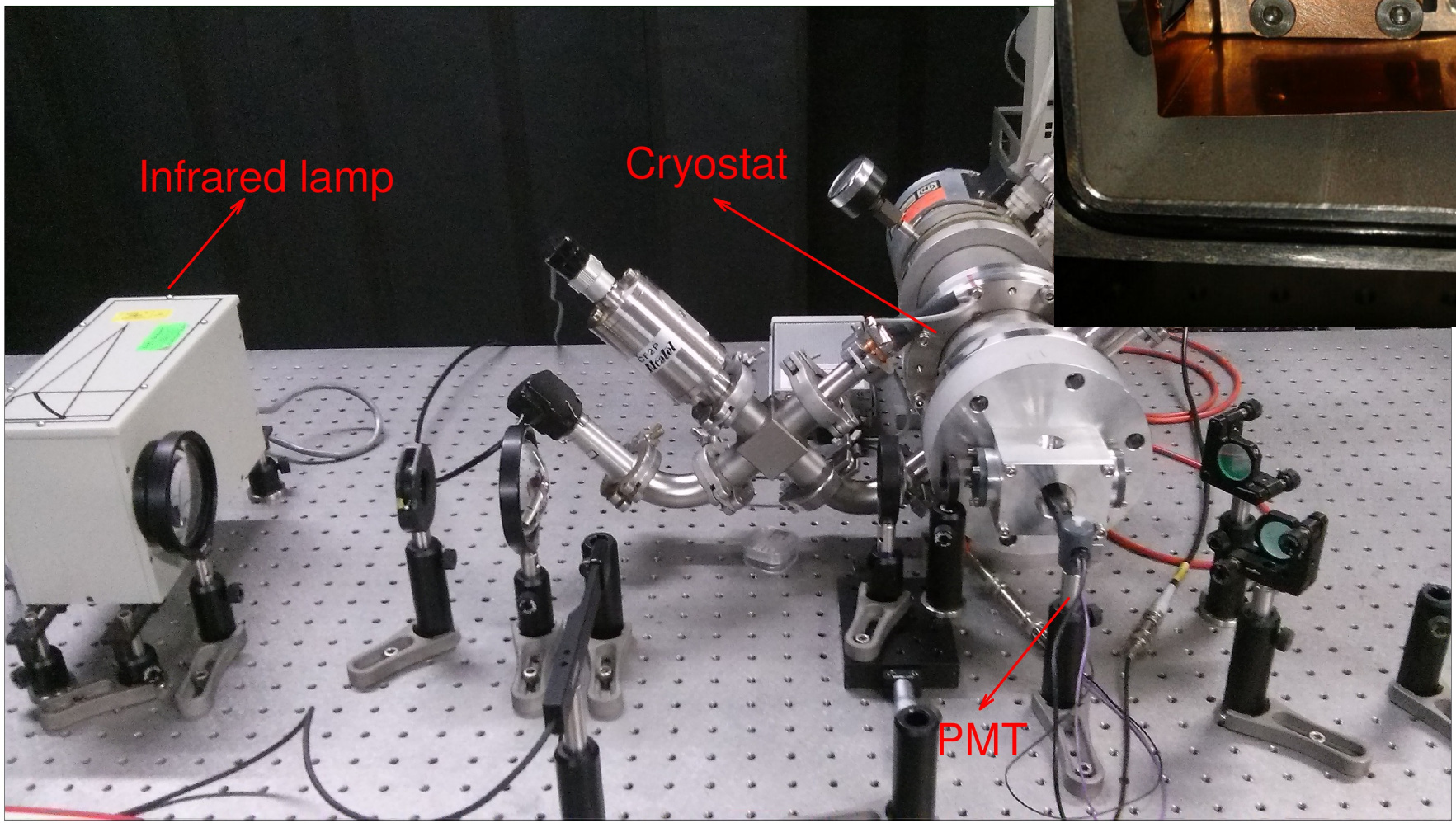


Nd^{3+}:YAG 1.1%		
Manifold	Optical range [nm]	LY [ph/MeV]
$^2F(2)_{5/2}$	390-650	9400
$^4F_{3/2}$	800-1500	50000

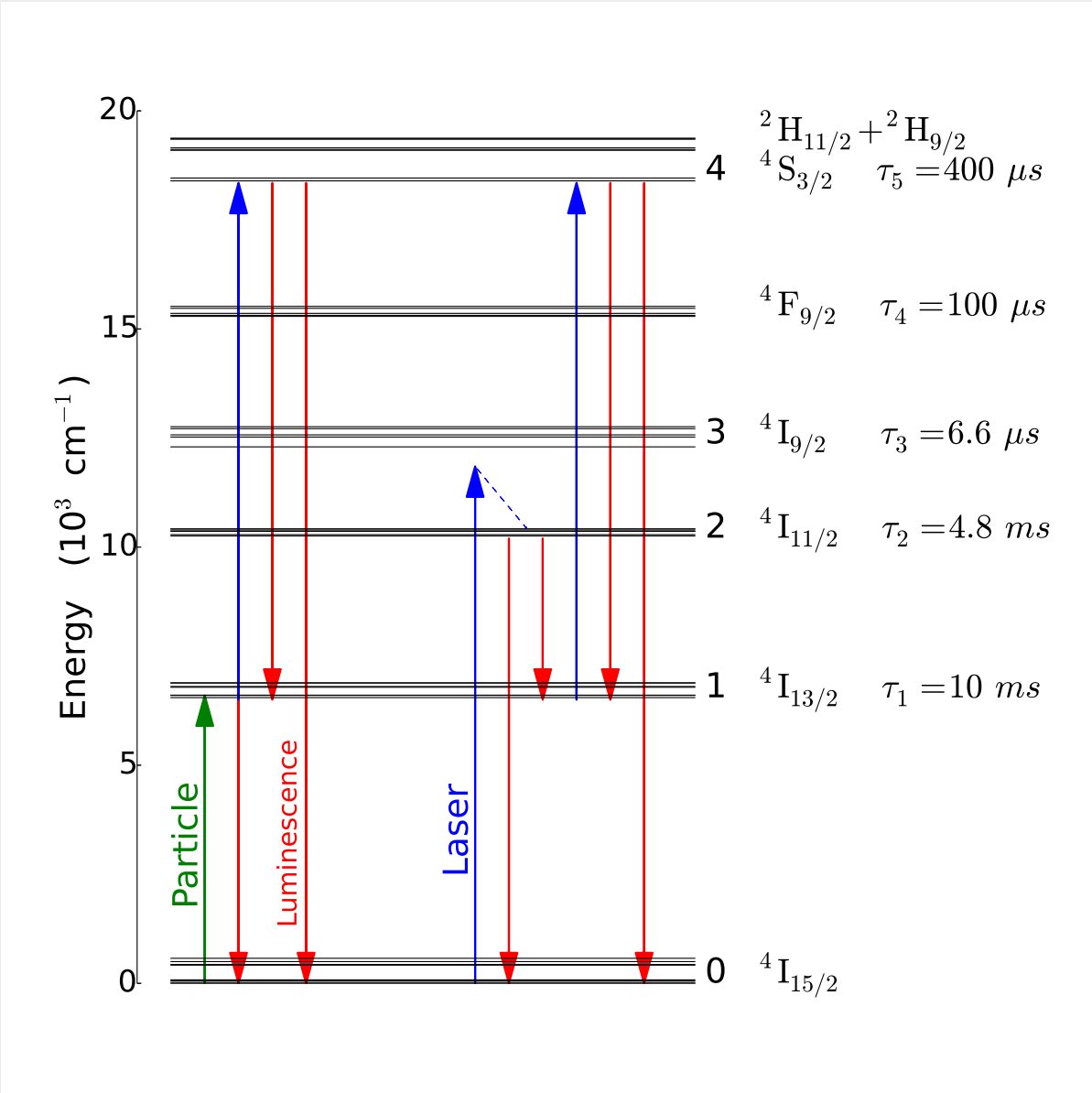
Tm^{3+}:YAG 4.4%		
Manifolds	Optical range [nm]	LY [ph/MeV]
$^1I_6, ^1D_2, ^1G_4, ^3H_4$	280-900	7000
$^3F_4$	1600-2300	45000

Setup for upconversion study

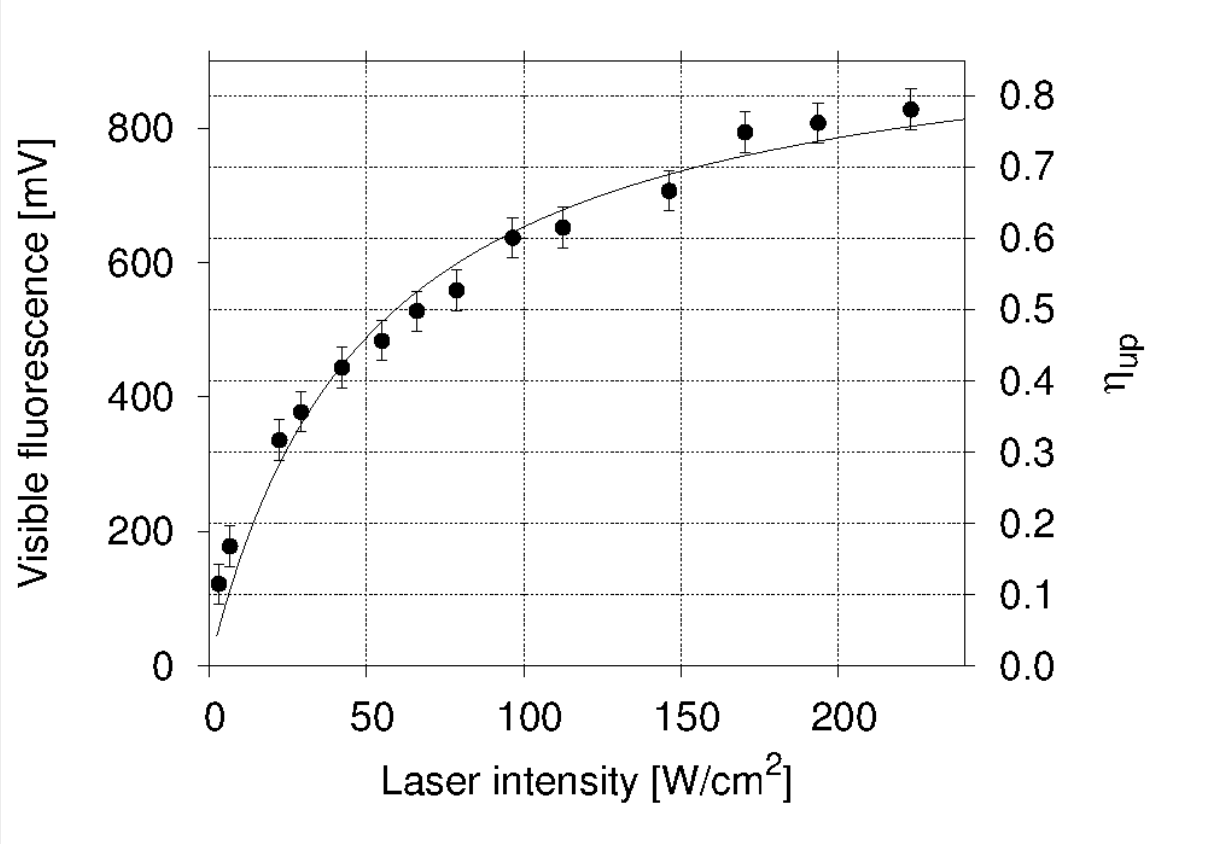




Upconversion and laser double resonance scheme in Er:YLF

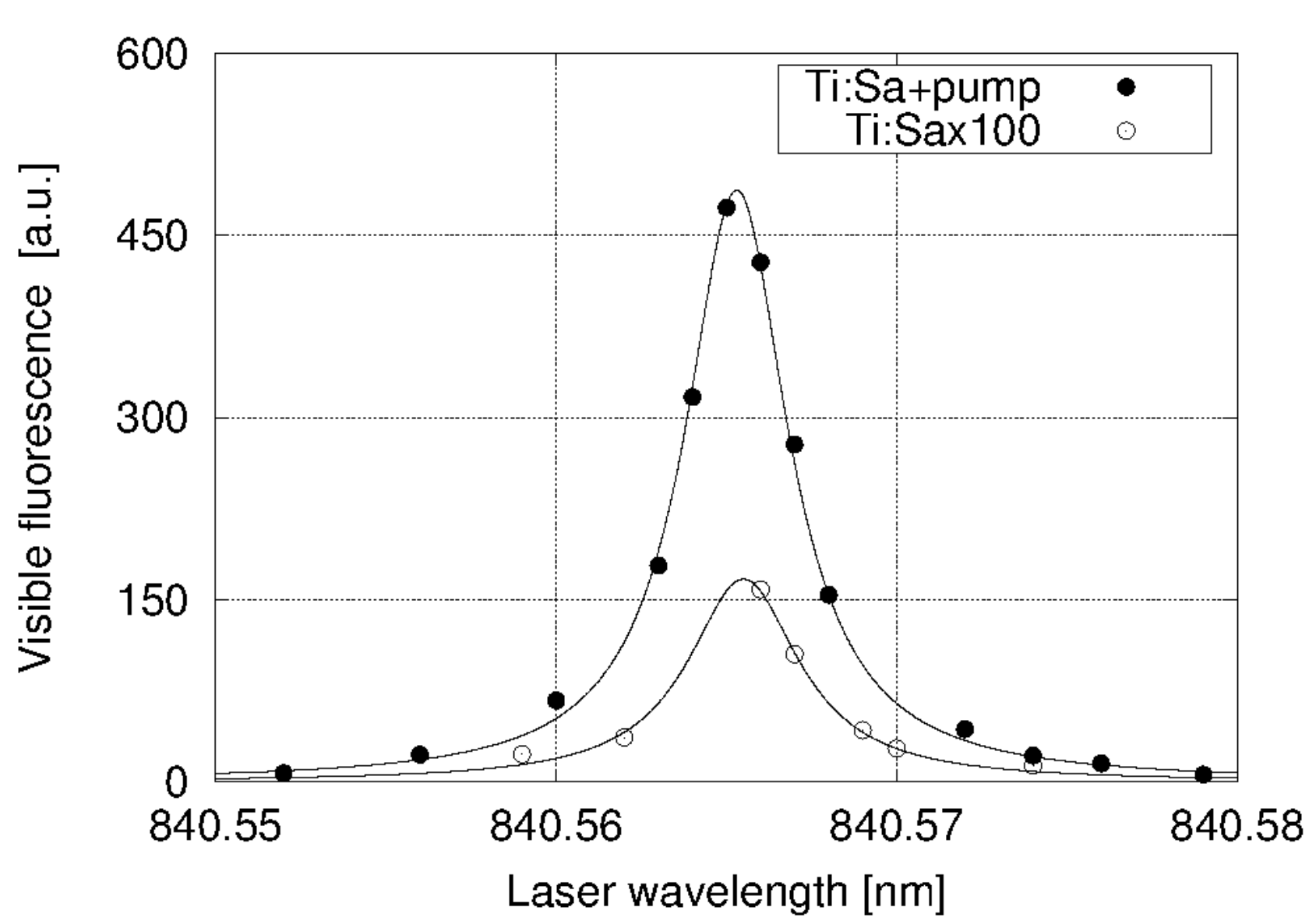


Upconversion efficiency in Er:YLF



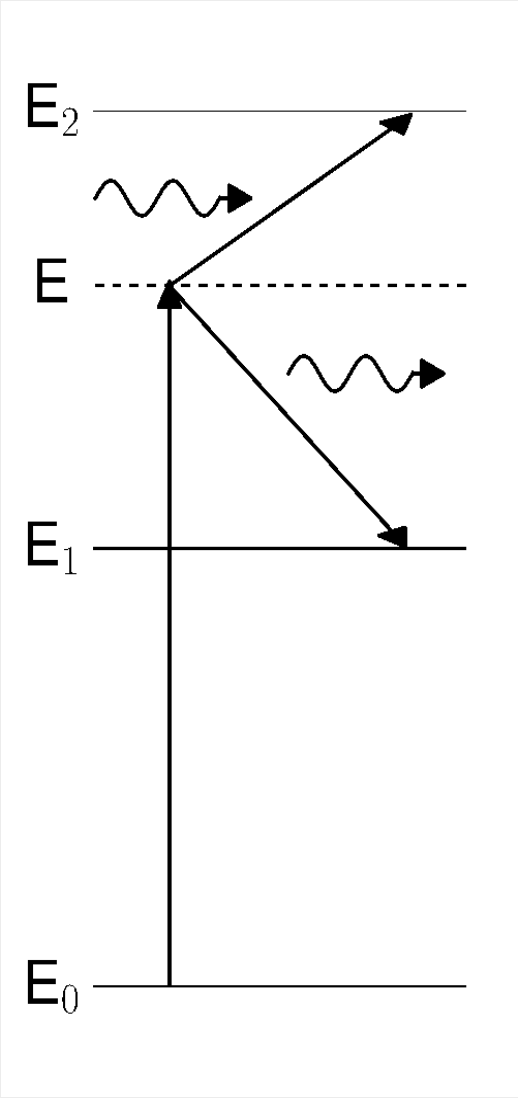
$$\eta_{\mathrm{up}}(I) = \frac{\beta_{40}}{\beta_{41}} \left(\frac{1}{\beta_{41} \frac{\sigma_{14}\tau_1 I}{\sigma_{14}\tau_1 I + h\nu}} - 1 \right)^{-1}$$

Upconversion and laser double resonance in Er:YLF 1%



"Noise" source: multiphonon assisted absorption

$$I(E) = I(E_1)\exp[-\alpha_S(E - E_1)] + I(E_2)\exp[-\alpha_{\mathrm{AS}}(E_2 - E)]$$



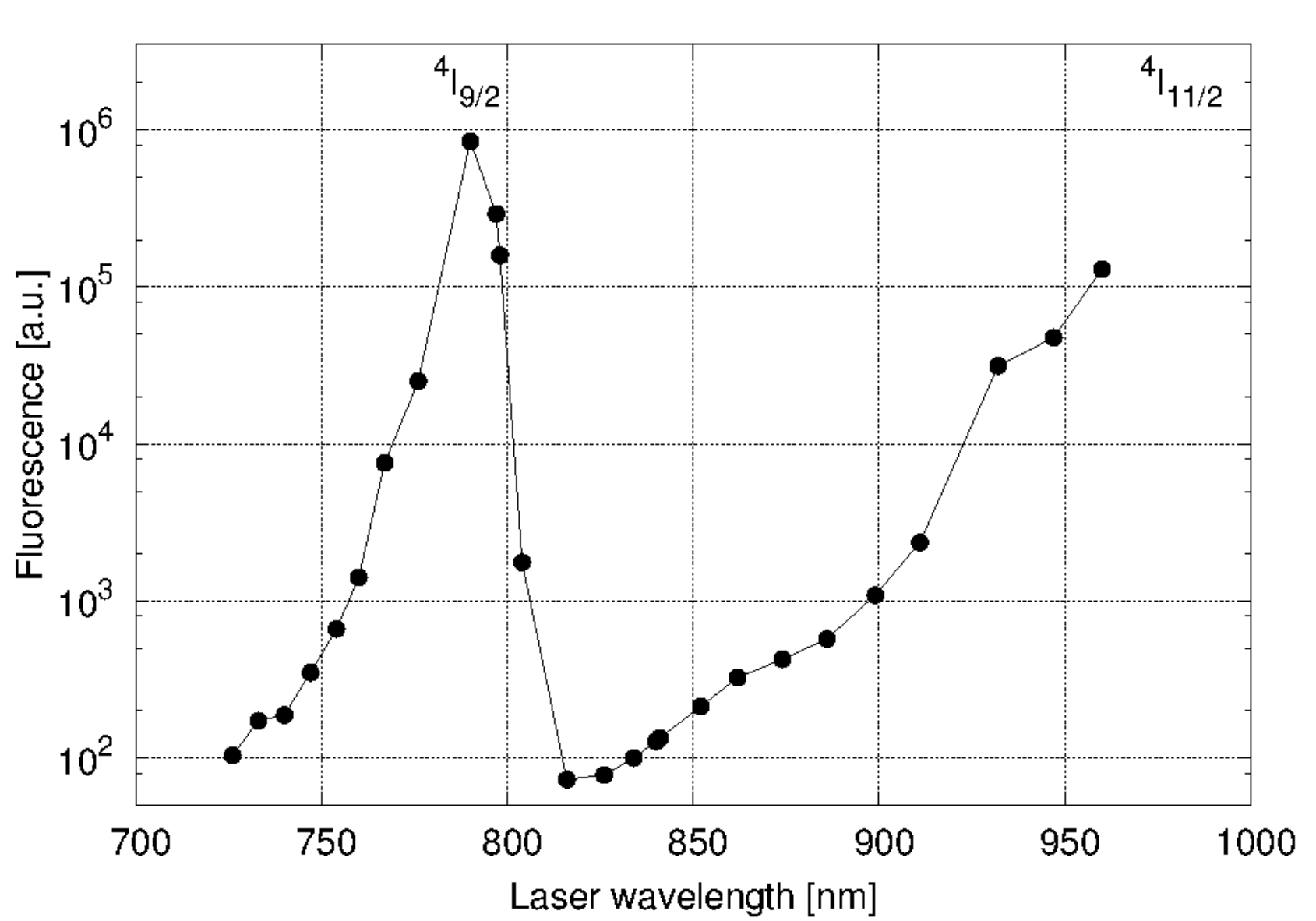
where

$$\alpha_S = \frac{1}{\hbar\omega_{\mathrm{eff}}} \ln\left[\frac{p}{S_0(n+1)} - 1\right]$$

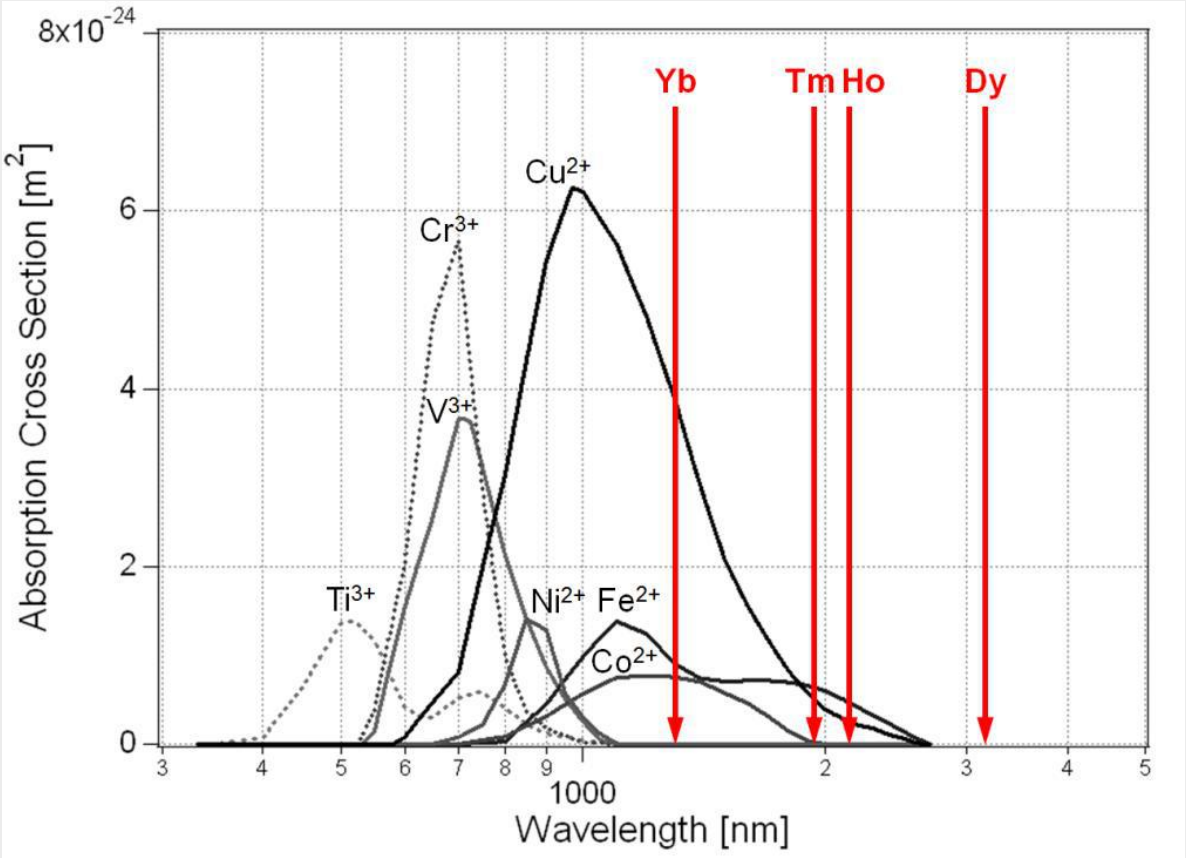
$$\alpha_{\mathrm{AS}} = \alpha_S + \frac{1}{kT}$$

$\hbar\omega_{\mathrm{eff}}$ is the effective phonon energy
$p =$ number of phonon needed to the process
$S_0 =$ Huang-Rhys parameter
$n(T)$ takes in account the bolzmann distibution

Non resonance multiphonon assisted absorption

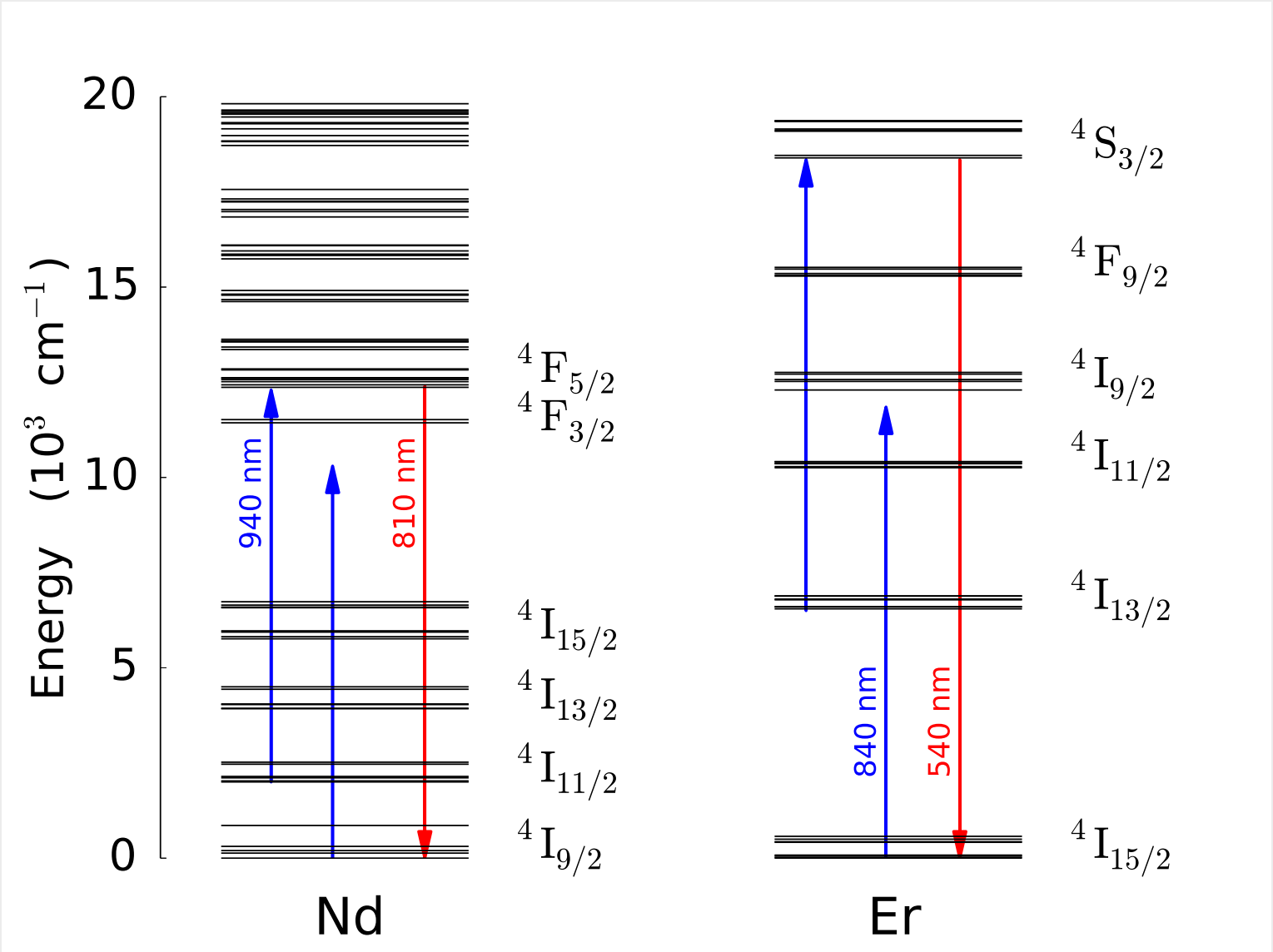


"Noise" source: impurities

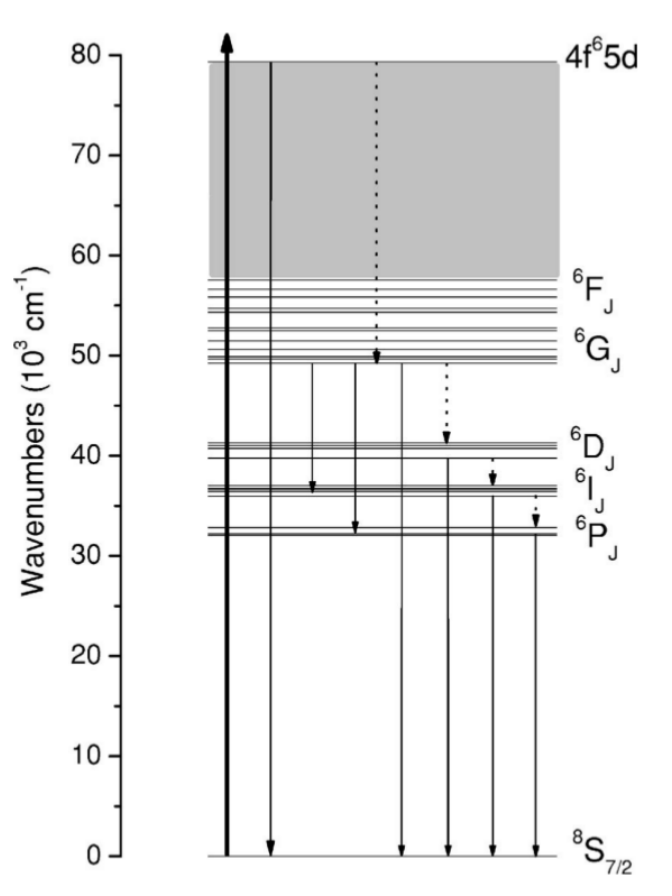


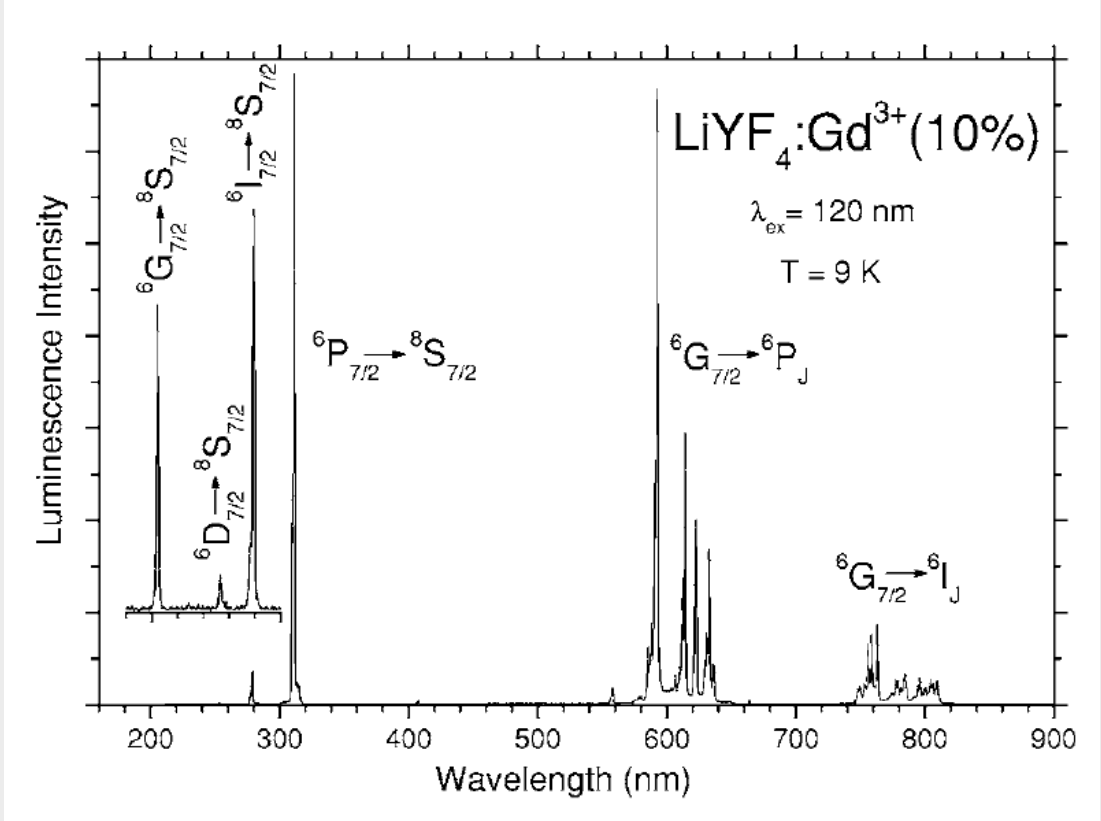
Hehlen, Markus P., et al. "Preparation of high-purity LiF, YF3, and YbF3 for laser refrigeration." SPIE OPTO. International Society for Optics and Photonics, 2014.

Upconversion in Nd:KPC and Nd:KPB



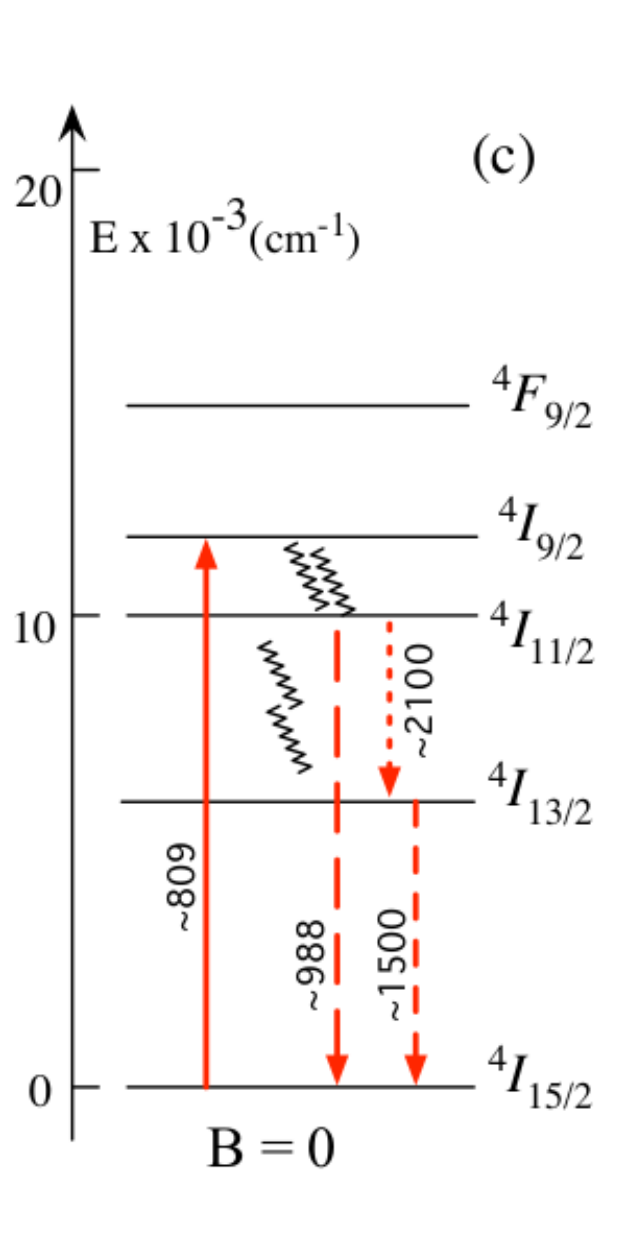
Volando più basso...

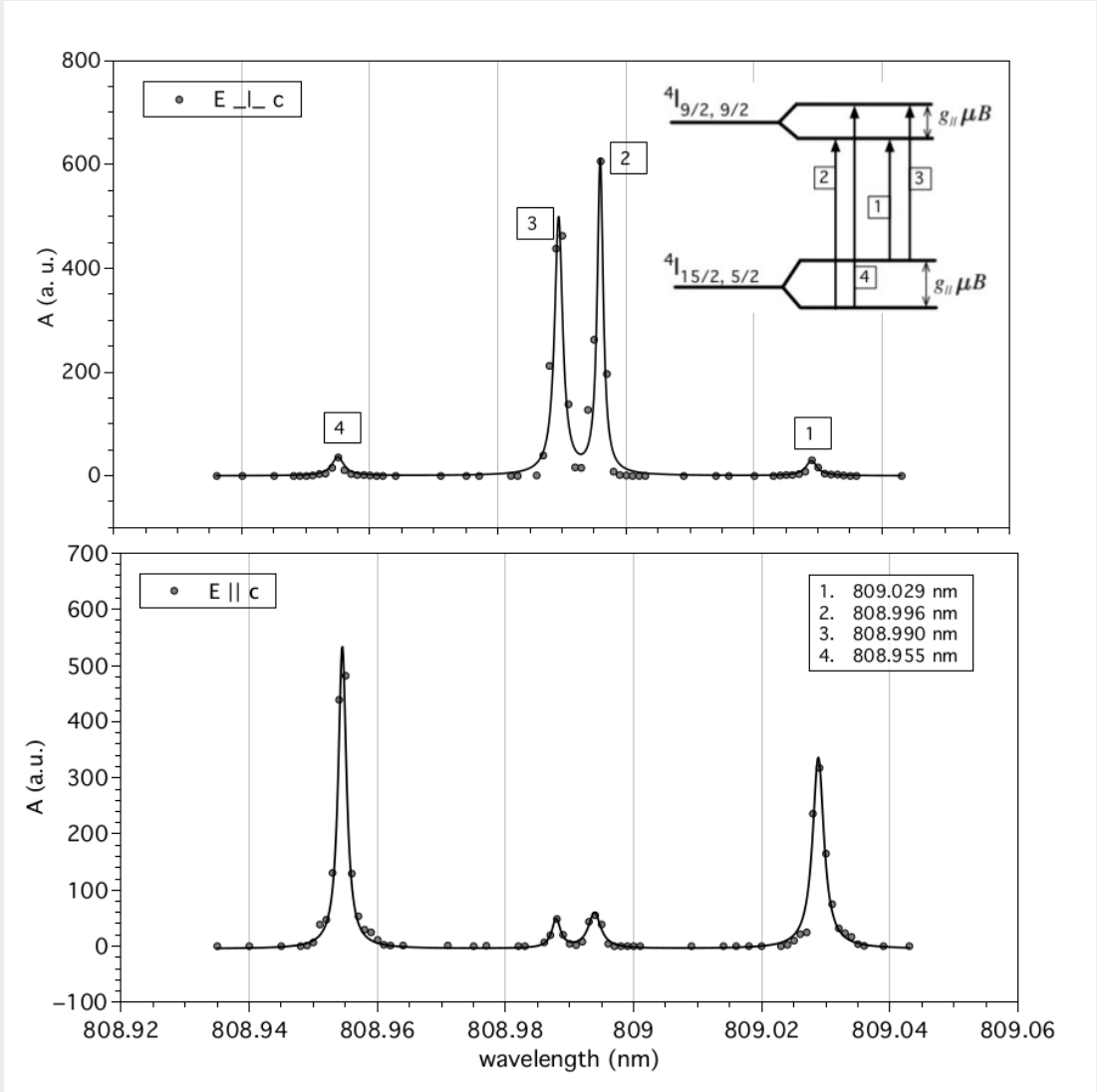




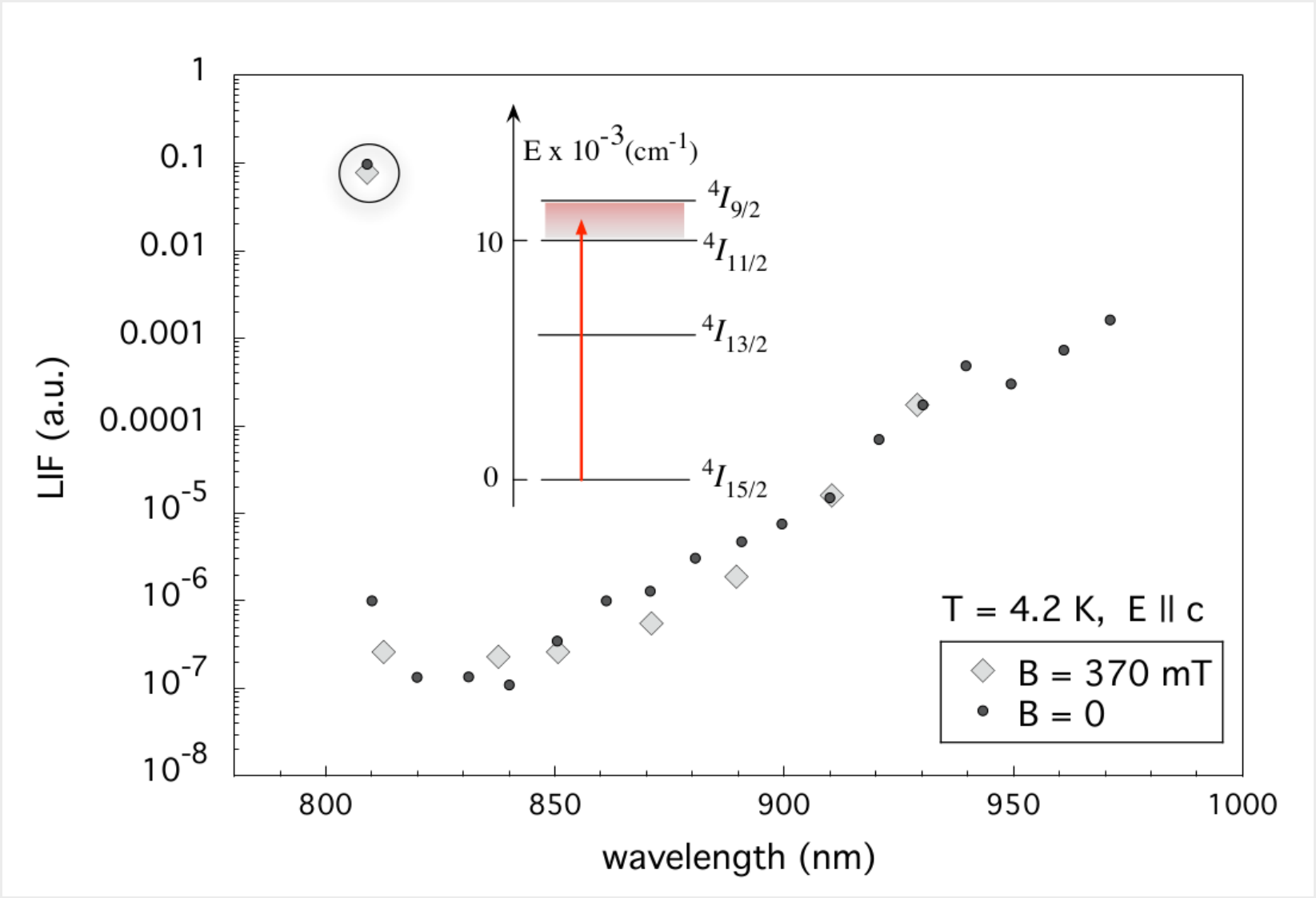
KIRM, M., et al. Vacuum-ultraviolet 5 d 4 f luminescence of Gd 3+ and Lu 3+ ions in fluoride matrices. Physical Review B, 2007, 75.7: 075111.

Axion dark matter detection scheme

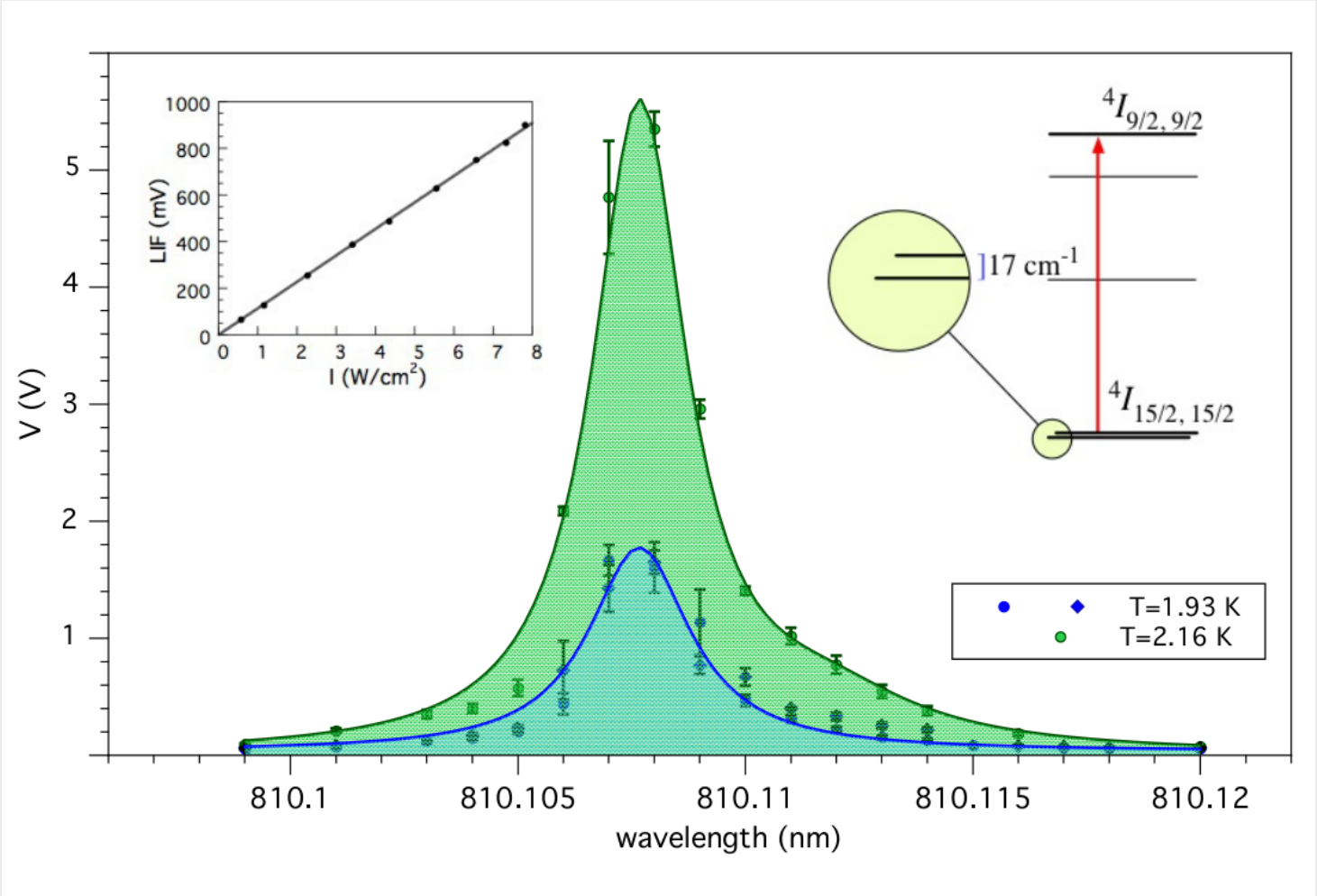




Noise source: multiphonon assisted absorption



Noise source: heating effects



$$LIF \propto I \cdot Ne^{\frac{-\Delta E}{kT}} \approx \beta[I(T_{LHE} + \alpha I)] \qquad \alpha < 0.2K/W$$