Micro-Pulling Down-Grown Nd^{3+}: $(La_{1-x},Ba_x)F_{3-x}$ as New Vacuum Ultraviolet Scintillator and Potential Laser Material

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Next target: Shorter wavelength region

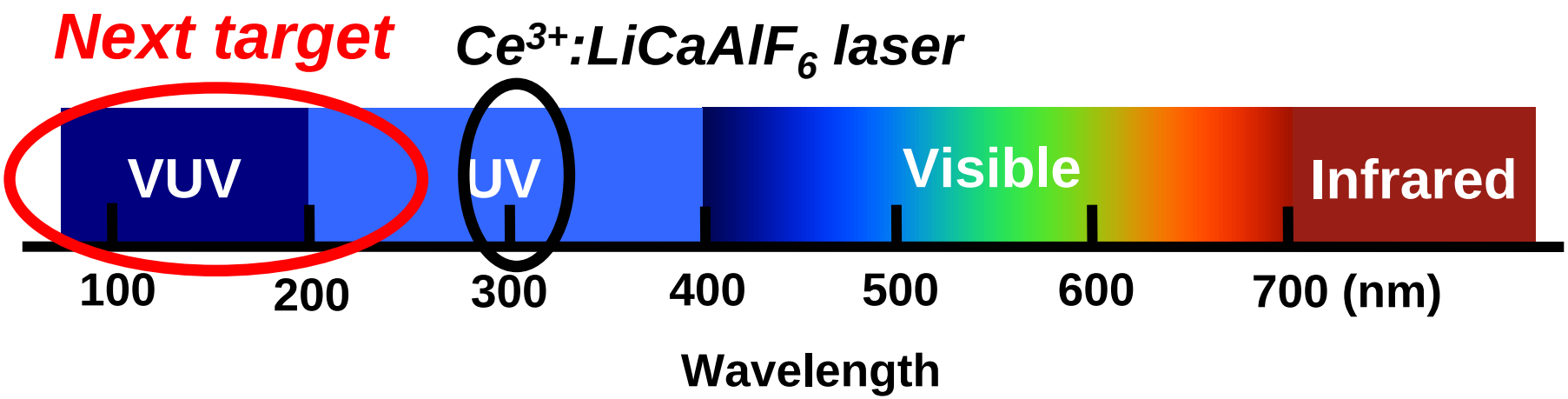
Deep ultraviolet (DUV) region

(250-180 nm)

and

Vacuum ultraviolet (VUV) region

(180 nm – 50 nm)



Suitable material for VUV scintillator and all solid – state VUV laser ?

$Nd^{3+}:LaF_3$ Emission in the VUV

- **Optical pumping**

Efficient $LaF_3:Nd^{3+}$-based vacuum-ultraviolet laser at 172 nm

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Vacuum-ultraviolet (VUV) laser radiation at 172 nm has been obtained from a solid-state $LaF_3:Nd^{3+}$-based laser pumped by a pulsed-discharge molecular F_2 laser at 157 nm. The maximum slope efficiency of the solid-state laser described in this experiment was 21% (14% conversion efficiency), and the maximum output energy at 172 nm was 0.4 mJ for a nonoptimized optical cavity. This finding introduces serious prospects for realizing versions of active-medium-plus-source tunable VUV laser devices.

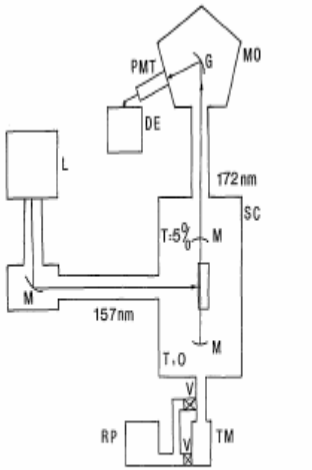

Fig. 2. Experimental layout. L, pulsed-discharge F_2 molecular laser at 157 nm; M's, mirrors; SC, stainless-steel vacuum chamber; MO, monochromator; G, grating; PMT, photomultiplier; DE, detection electronics; TM, turbo molecular pump; RP, rotary pump; V's, valves.

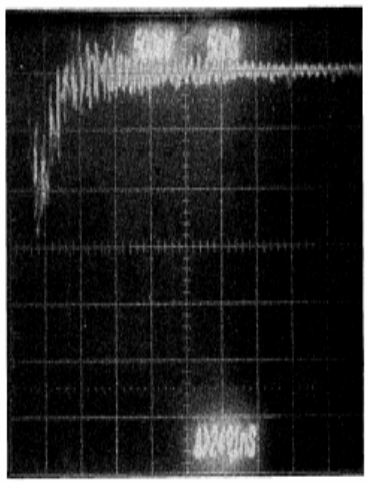

Fig. 4. Temporal evolution of the laser pulse from the $LaF_3:Nd^{3+}$ crystal at 172 nm.

JOSA B 9, 1148 (1992)

- **Electron beam pumping**

Vacuum ultraviolet laser emission from $Nd^{+3}:LaF_3$

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Laser emission at 172 nm has been produced by pumping a Nd:LaF_3 crystal with incoherent Kr_2^* radiation at 146 nm. The 5-ns pulse contained approximately 20–30 μJ of energy. Fluorescence measurements indicate potential for tuning from 170–175 nm, which should be observable with OH^--free crystals.

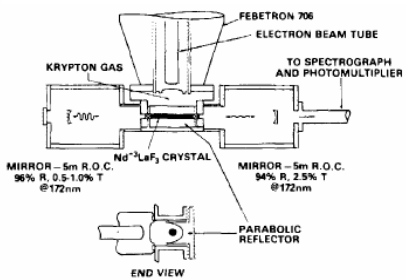


FIG. 1. Excitation system for rapid pumping of $Nd^{3+}:LaF_3$.

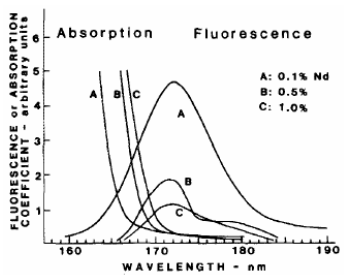


FIG. 3. Absorption spectra of $Nd^{3+}:LaF_3$ samples, superimposed on the fluorescence spectra of Fig. 2.

App. Phys. Lett. 46, 14 (1985)

$Nd^{3+}:LaF_3$ Emission in the VUV

- Restricted tunability (170 – 175 nm)
- Electron beam pumping
- All-solid-state VUV laser needed

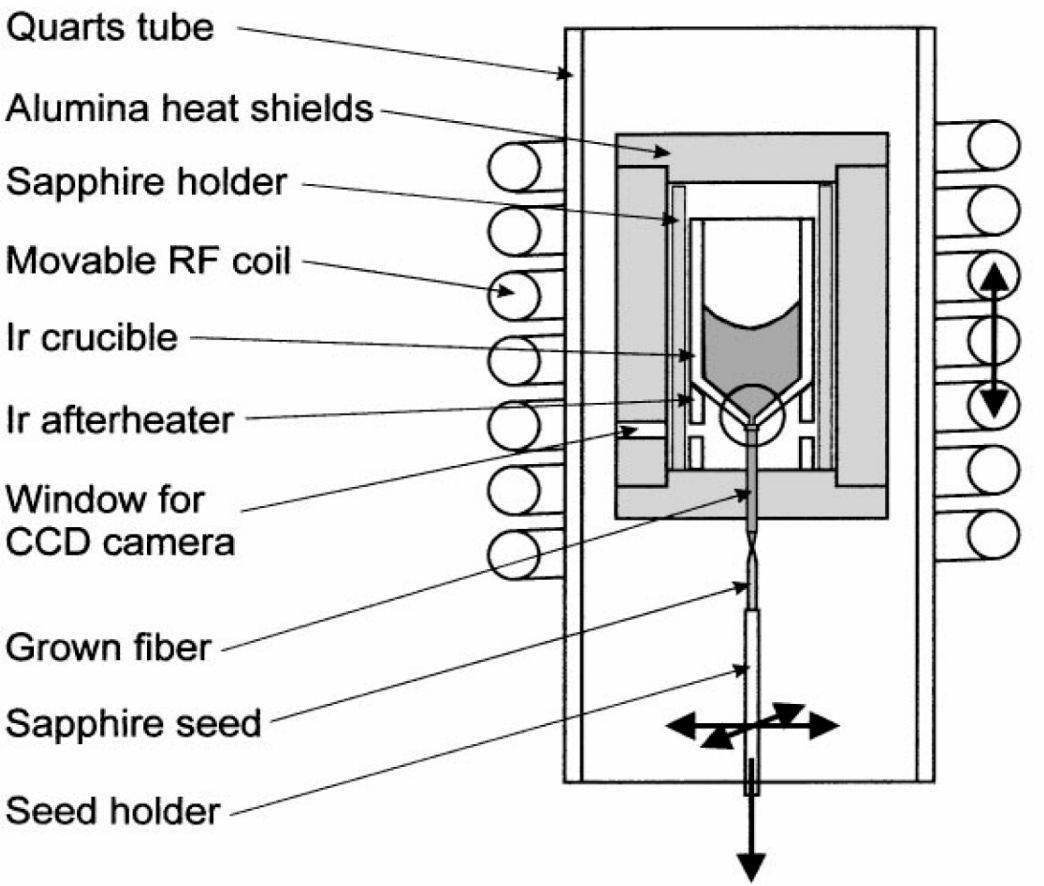
Looks attractive but not so much follow-up work

Purpose

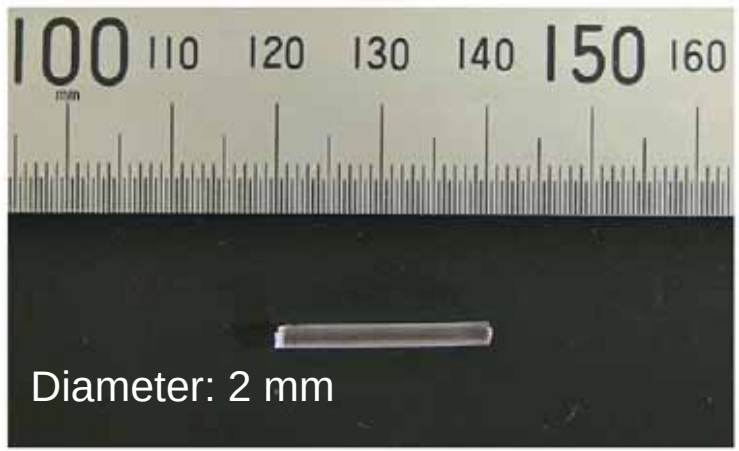
"Investigate Nd^{3+}: $(La_{1-x},Ba_x)F_{3-x}$ (x=0.1) grown by Micro – PD method as new VUV scintillator and potential laser material"

Growth of $Nd^{3+}:La_{(1-x)}Ba_xF_{(3-x)}$ (x=0.1) by Micro-Pulling Down Method

Micro-PD apparatus for fluoride crystal growth

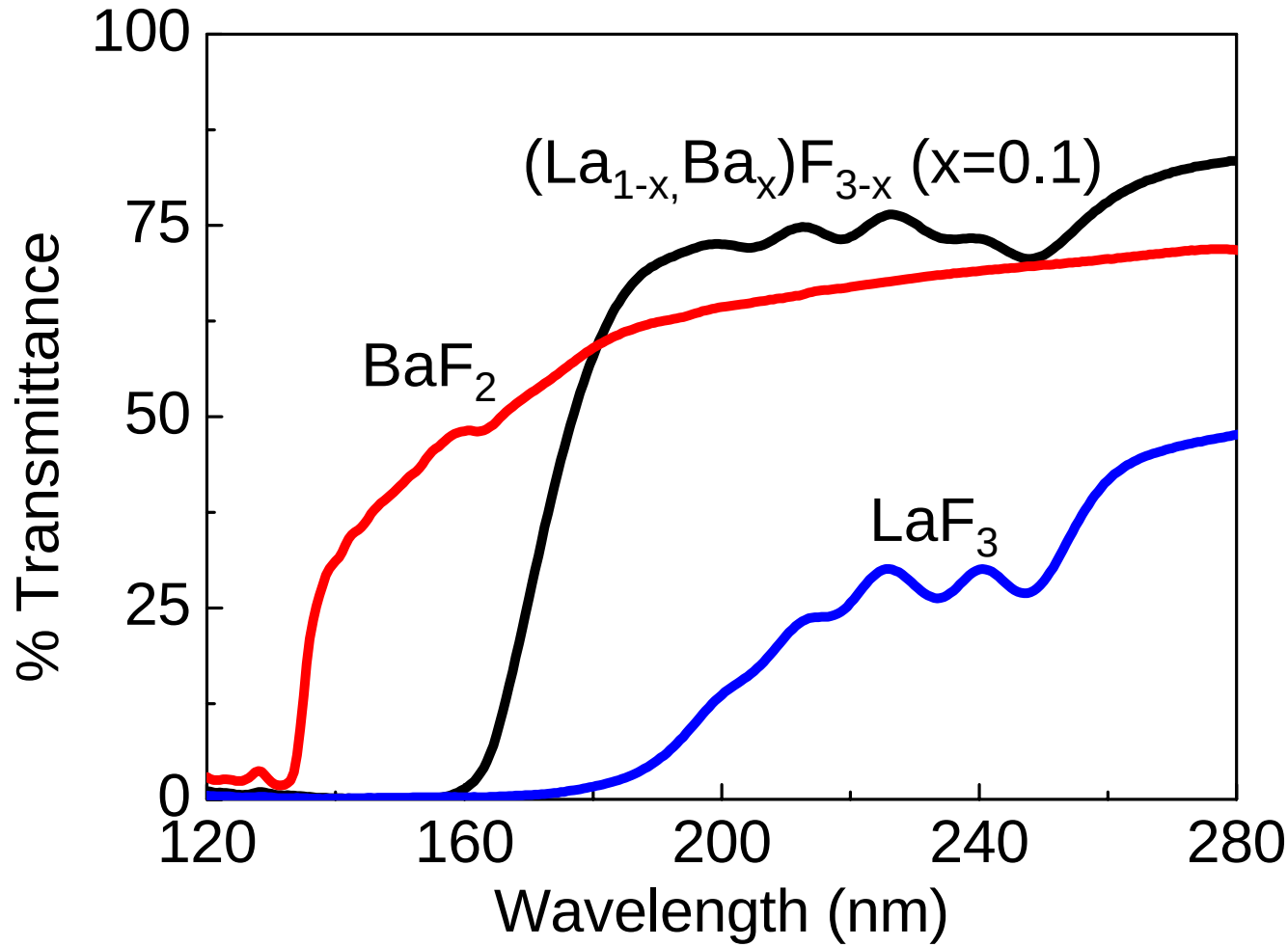


Nd^{3+}: $La_{(1-x)}Ba_xF_{(3-x)}$ (x=0.1) sample by Prof. Fukuda at Tohoku University



A. Yoshikawa, T. Satonaga, K. Kamada, H. Sato, M. Nikl, N. Solovieva,T. Fukuda, **J. Cryst. Growth 270, 427 (2004)**

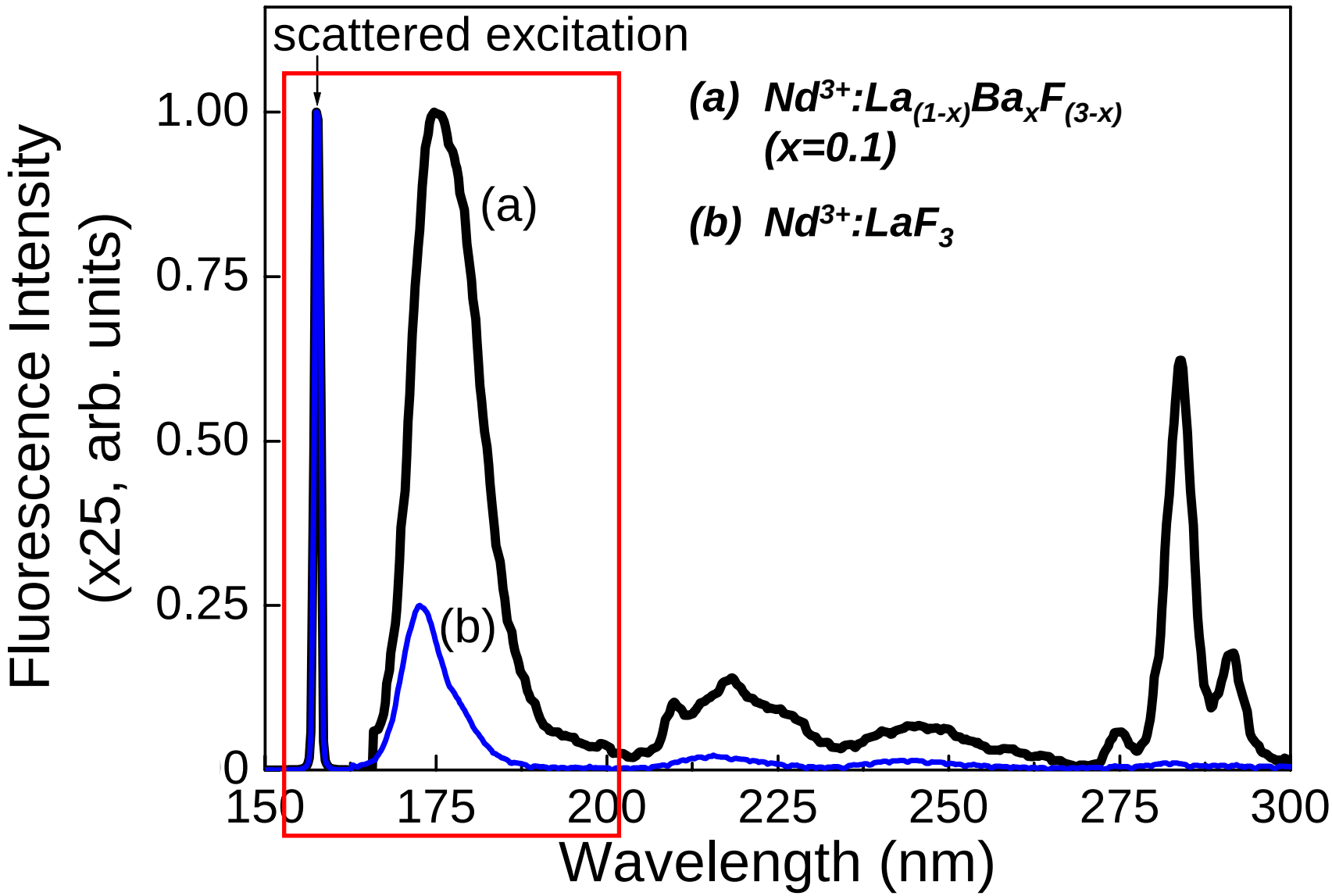
Transmission Characteristics of $La_{(1-x)}Ba_xF_{(3-x)}$ (x=0.1) and LaF_3



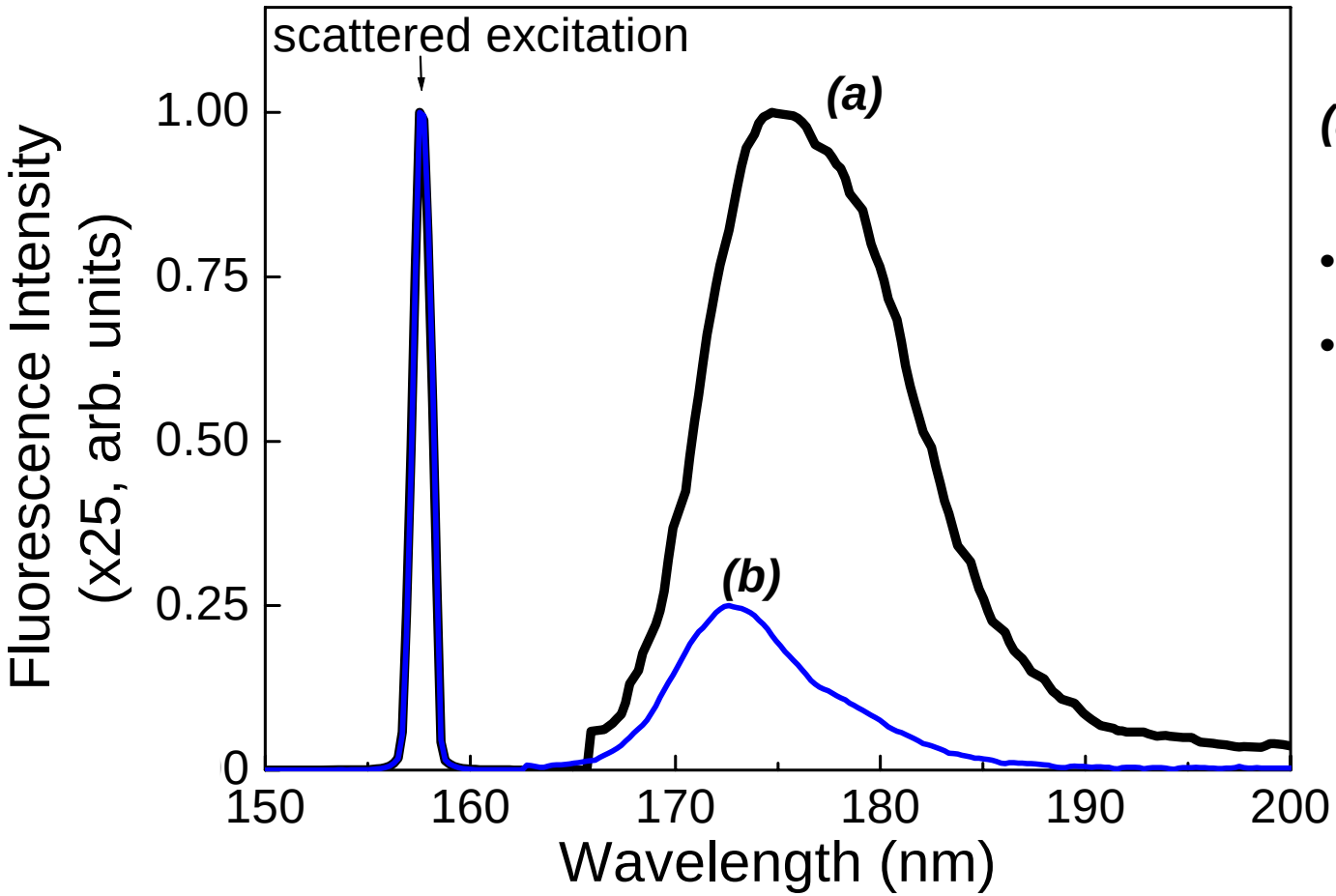
Transmission Edges:

BaF_2 : 134 nm **$(La_{1-x,}Ba_x)F_{3-x}$: 160 nm** **LaF_3 : 180 nm**

Fluorescence spectra of $Nd^{3+}:La_{(1-x)}Ba_xF_{(3-x)}$ (x=0.1) and $Nd^{3+}:LaF_3$



VUV Fluorescence spectra of $Nd^{3+}:La_{(1-x)}Ba_xF_{(3-x)}$ (x=0.1) and $Nd^{3+}:LaF_3$



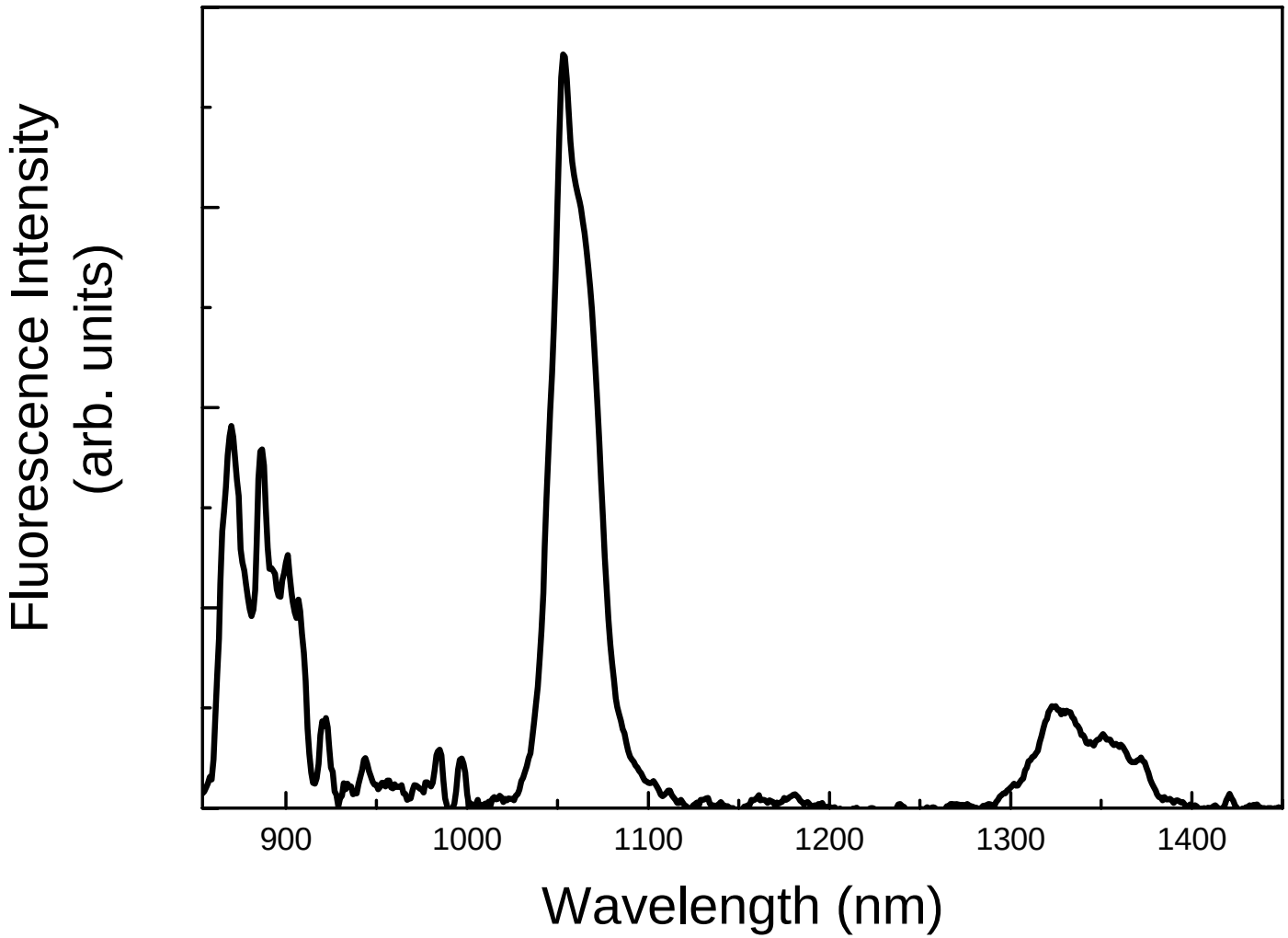
(a) $Nd^{3+}:La_{(1-x)}Ba_xF_{(3-x)}$ (x=0.1)

- Peak: 175 nm
- FWHM: 12 nm

(b) $Nd^{3+}:LaF_3$

- Peak: 172 nm
- FWHM: 8 nm

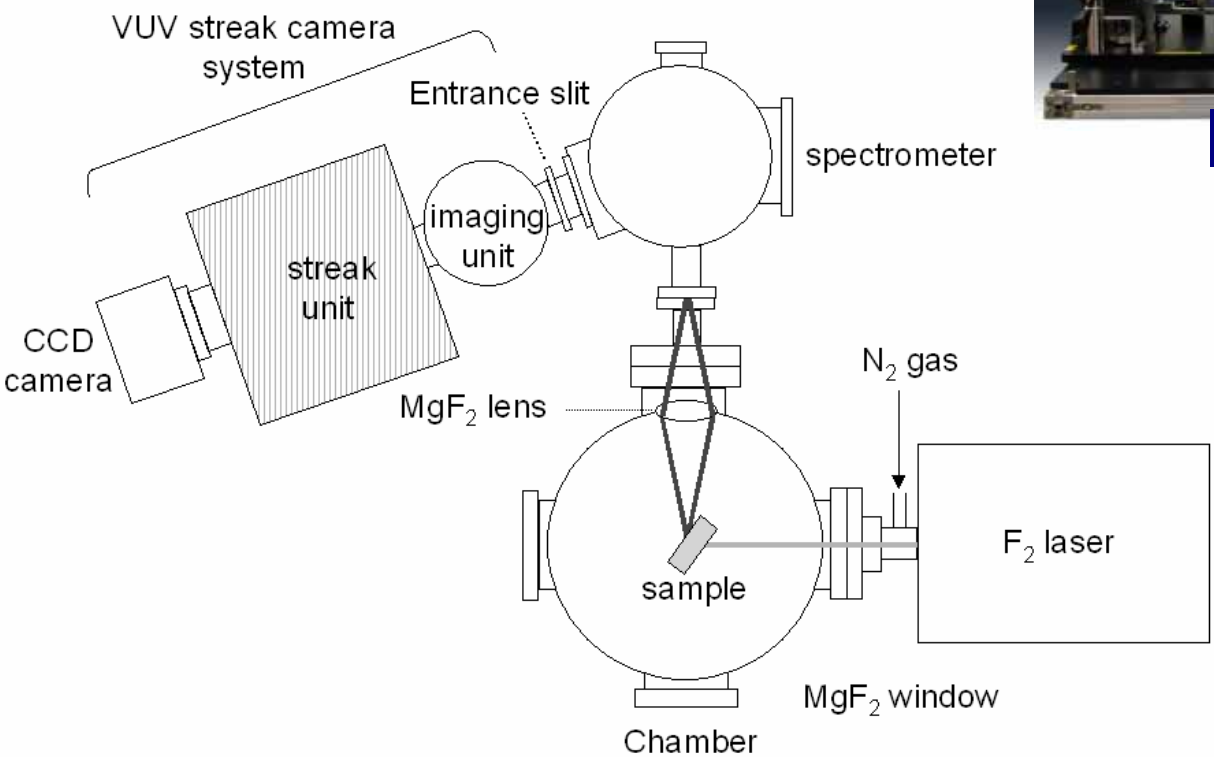
IR Fluorescence spectra of $Nd^{3+}:La_{(1-x)}Ba_xF_{(3-x)}$ (x=0.1)



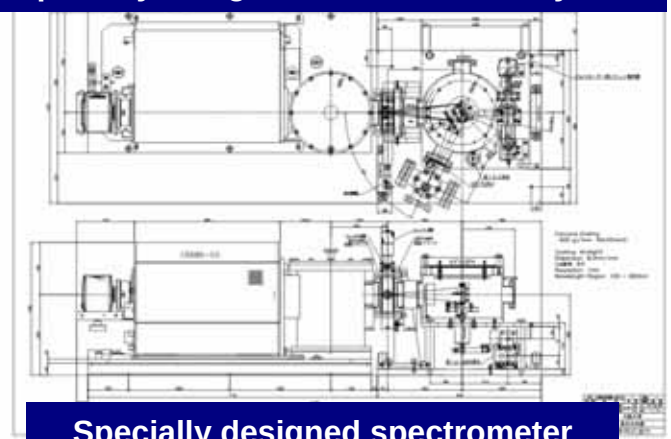
Excitation wavelength: 800 nm

Peak: 1053 nm

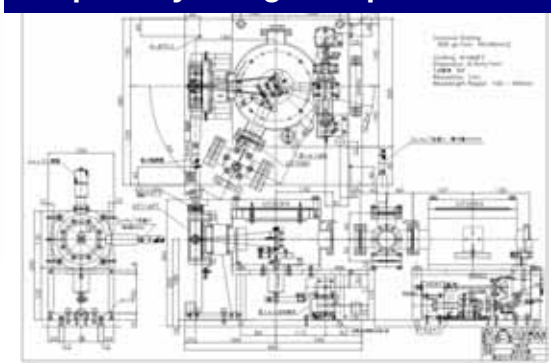
Experiment: Set – up for Evaluating VUV Fluorescence Lifetime of $Nd^{3+}:La_{(1-x)}Ba_xF_{(3-x)}$ (x=0.1)



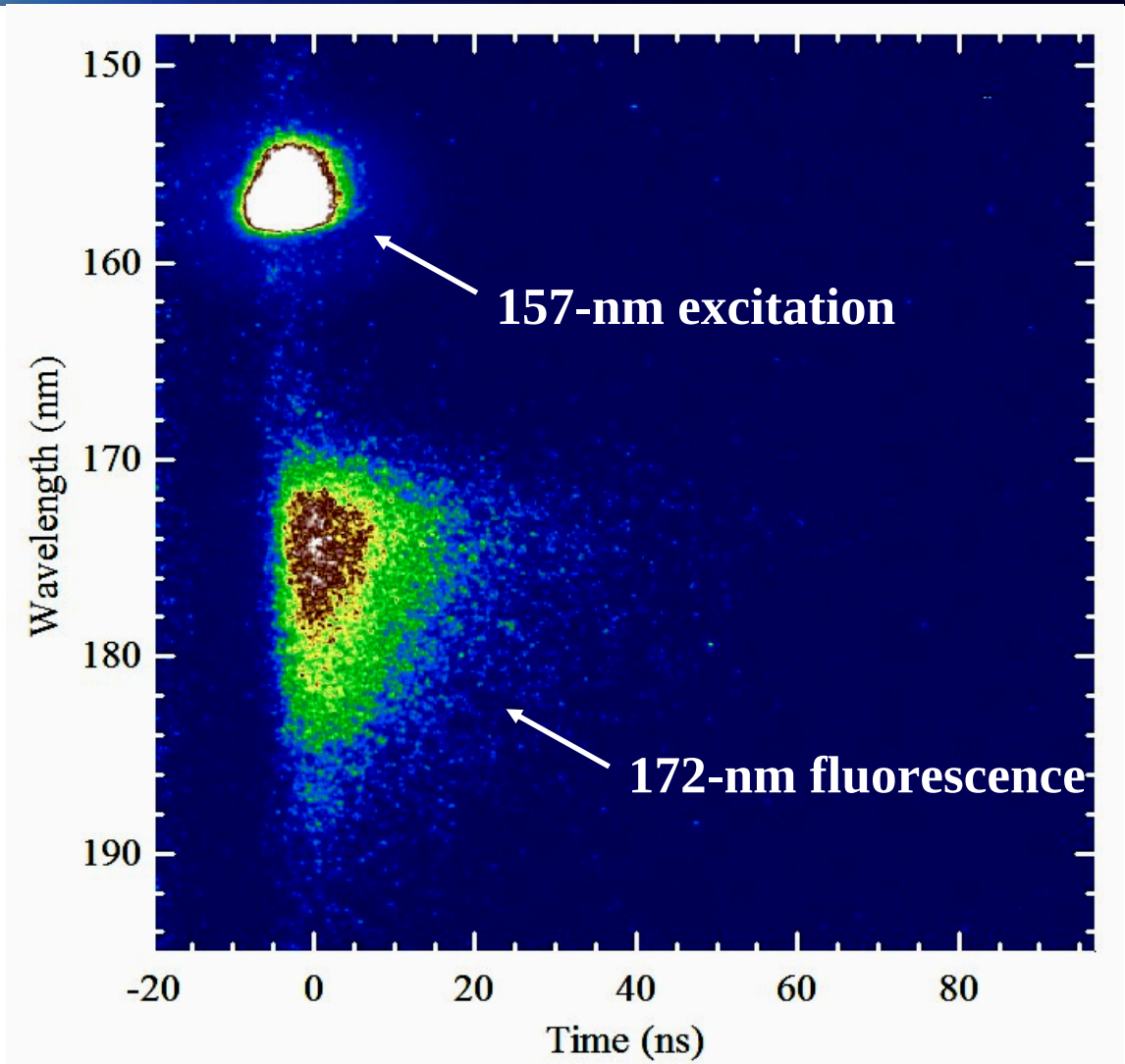
Specially designed streak camera system



Specially designed spectrometer

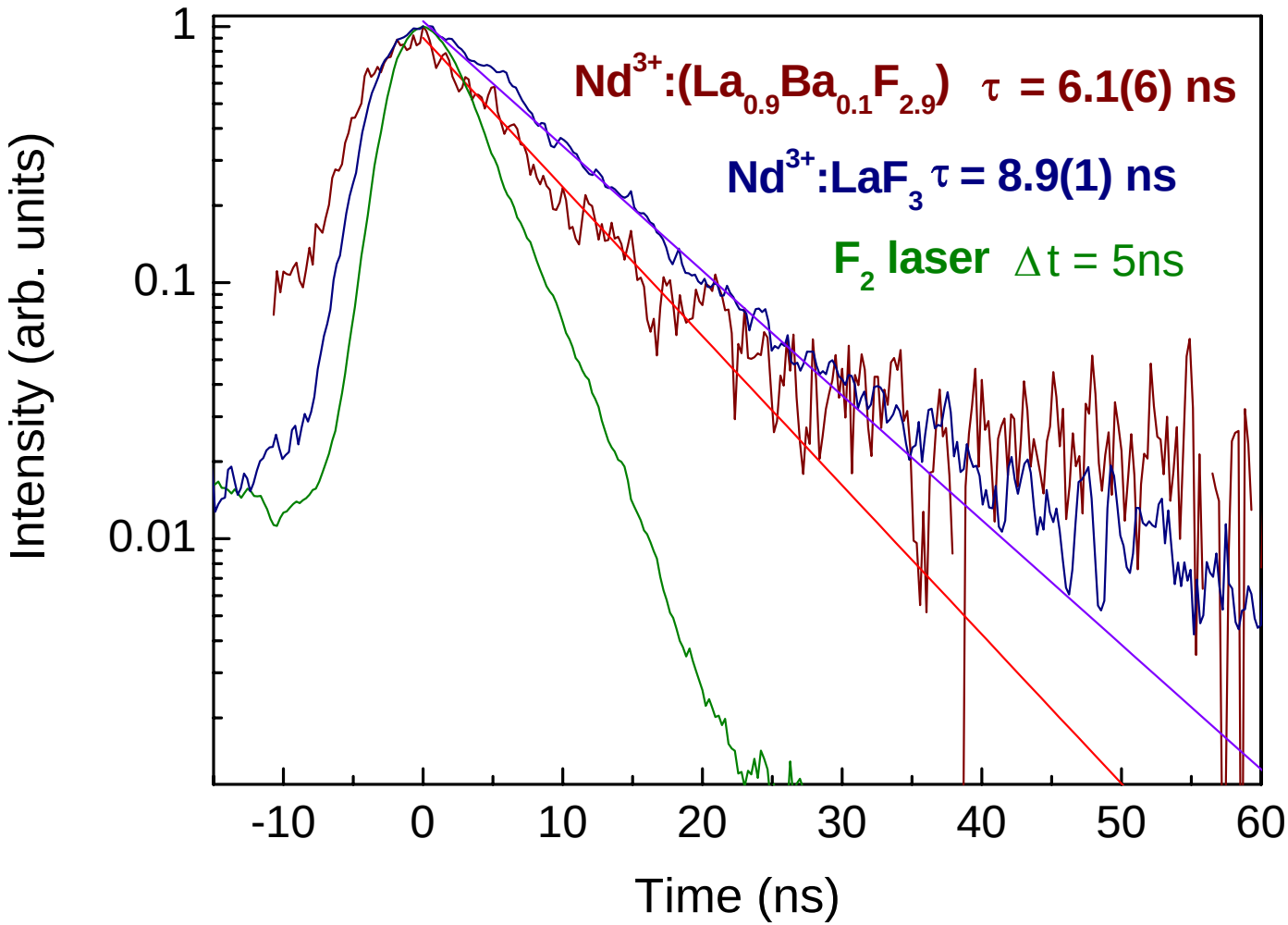


Experiment: Streak Camera Image of $Nd^{3+}:LaF_3$ Fluorescence



First VUV streak camera image

Experiment: $Nd^{3+}:(La_{1-x}Ba_xF_{3-x})$ (x=0.1) and $Nd^{3+}:LaF_3$ Temporal Profile



$Nd^{3+}:(La_{1-x,}Ba_x)F_{3-x}$ (x=0.1) fluorescence decays faster

Summary

- $Nd^{3+}:(La_{1-x,}Ba_x)F_{3-x}$ (x = 1) single crystal is successfully grown using the micro-Pulling Down method.

- Undoped $Nd^{3+}:(La_{1-x,}Ba_x)F_{3-x}$ (x = 1) sample has short transmission edge at 160 nm compared to LaF_3 at 180 nm.

- Strong VUV fluorescence with peak located at 175 nm.

- Broad VUV fluorescence with FWHM of 12 nm compared to $Nd^{3+}:LaF_3$ with FWHM of 8 nm.

[1] M. Cadatal.et al, J. Appl. Phys., 46 (2007) L985 - L987.

[2] M. Cadatal,et al, J. Opt. Soc. Am. B in press