

Instrumentation for X-ray excited and laser induced fluorescence lifetime spectroscopy – Time resolved decay spectra for characterization of fluorescence materials using two-dimensional photon counting

Introduction

The classic way of scintillator characterization and testing such materials is based on time-correlated single photon counting (TCSPC). The excitation process is induced by radioactive isotopes such as ^{22}Na . Another way to excite a scintillator sample is a pulsed X-ray source.^[1] In the general instrumental set-up, very fast photomultiplier tubes generate the start and stop pulses. A disadvantage of these systems is the difficulty to get spectral information from the measured decay times. Streak camera systems have been a milestone in measuring X-Ray Excited Optical Luminescence (XEOL) because they offer the advantage to measure decay times and emission spectra simultaneously.^[2] Our system is based on a 40 kV pulsed X-ray tube and an optical path of light. This allows us to use the pulsed laser as excitation source for measuring optical induced fluorescence and to excite the X-ray tube.

Experimental

Figure 1 shows the housed X-ray tube N5084 with optics and streak system including CCD-camera. The instrumental set-up is given in figure 2. The delay generator as master clock gives synchronizing start pulses for the laser and the streak camera. The laser beam or the pulsed X-ray radiation excites the sample. The fluorescence light of the sample passes a collecting lens system and then is focused on the spectrograph. The electronics (spectrograph, streak camera, CCD camera) assimilate the signal to a streak image (Fig. 3) with 640x480 pixel where emission wavelength is plotted against time. From this image decay time and emission spectra are accessible. All measurements were taken under ambient air conditions and room temperature. The used substances were chemical pure (p.a.). Rhodamine 6G was dissolved in MeOH to a concentration of 10^{-6} M. The solution was measured in a quartz cuvette under pulsed laser excitation (repetition rate 10 MHz; $\lambda = 440$ nm). Cesium iodide and anthracene were pressed to pellets under 10 t of pressure. The pellets were measured under pulsed X-ray excitation (40 kV and 1.2 μA).

Results

The results are shown in figure 4-6. Cesium iodide (Fig. 4) has its emission maximum at 310 nm. To determine the decay time a biexponential fit was done which led to a $\tau = 1.68$ ns and $\tau = 10.21$ ns for the two components while the $\chi^2 = 1.0880$.^[3] The emission maximum of anthracene (Fig. 5) is at 450 nm. Its decay time was determined to $\tau = 2.36$ ns (Single exponential fit; $\chi^2 = 1.1471$).^[4] Rhodamine 6G (Fig. 6) shows an emission maximum at 560 nm. The decay time is 4.42 ns.^[5] The described system provides us with decay times and emission spectra which are corresponding to the literature.^[3-5] Decay time fits were performed by Hamamatsu HPD-TA fit software.

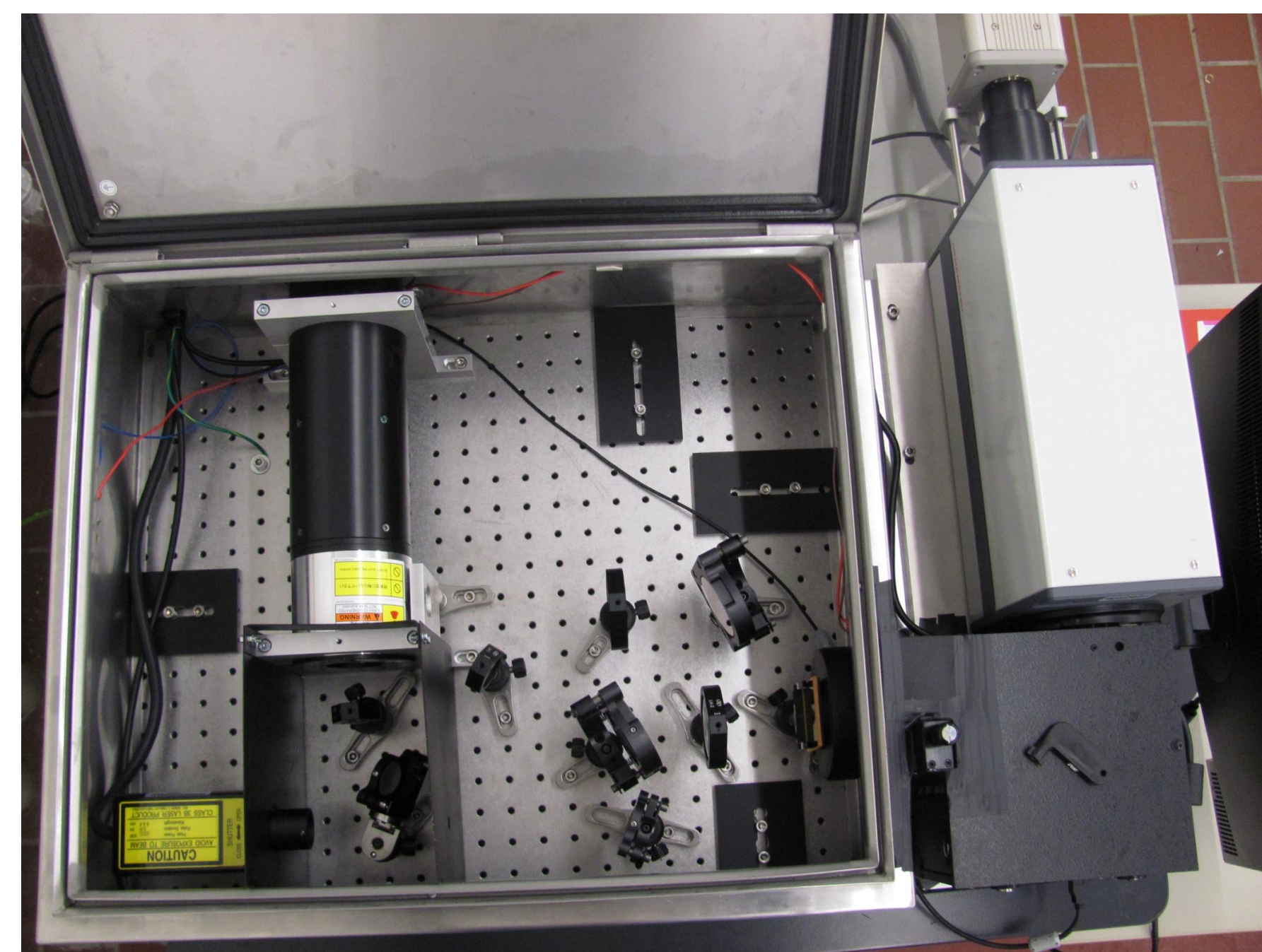


Fig.1: Housed X-ray tube N5084 with laser head, optics, spectrograph & streak camera (included CCD-camera)

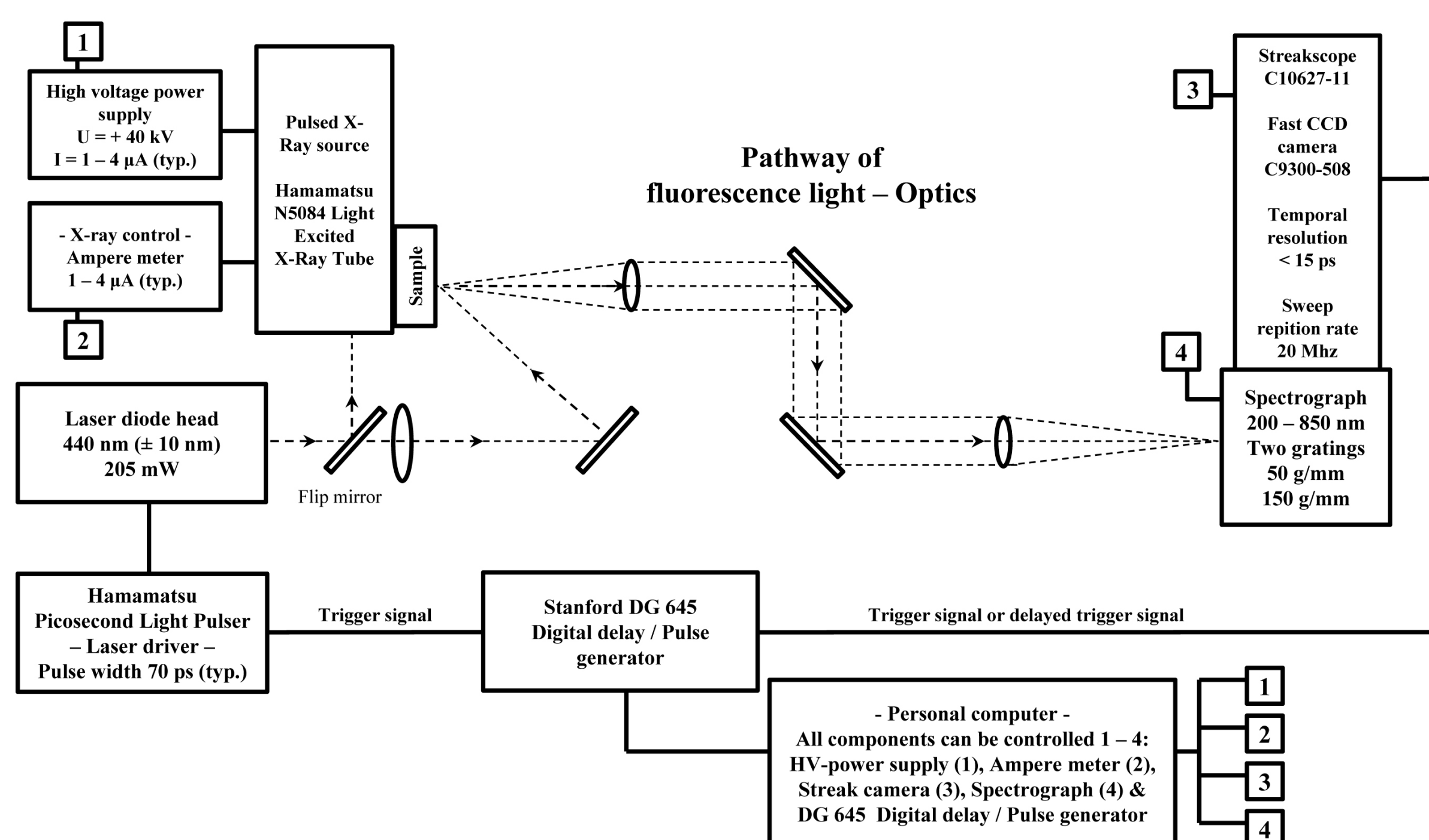


Fig. 2: Scheme of measurement and instrumental set-up

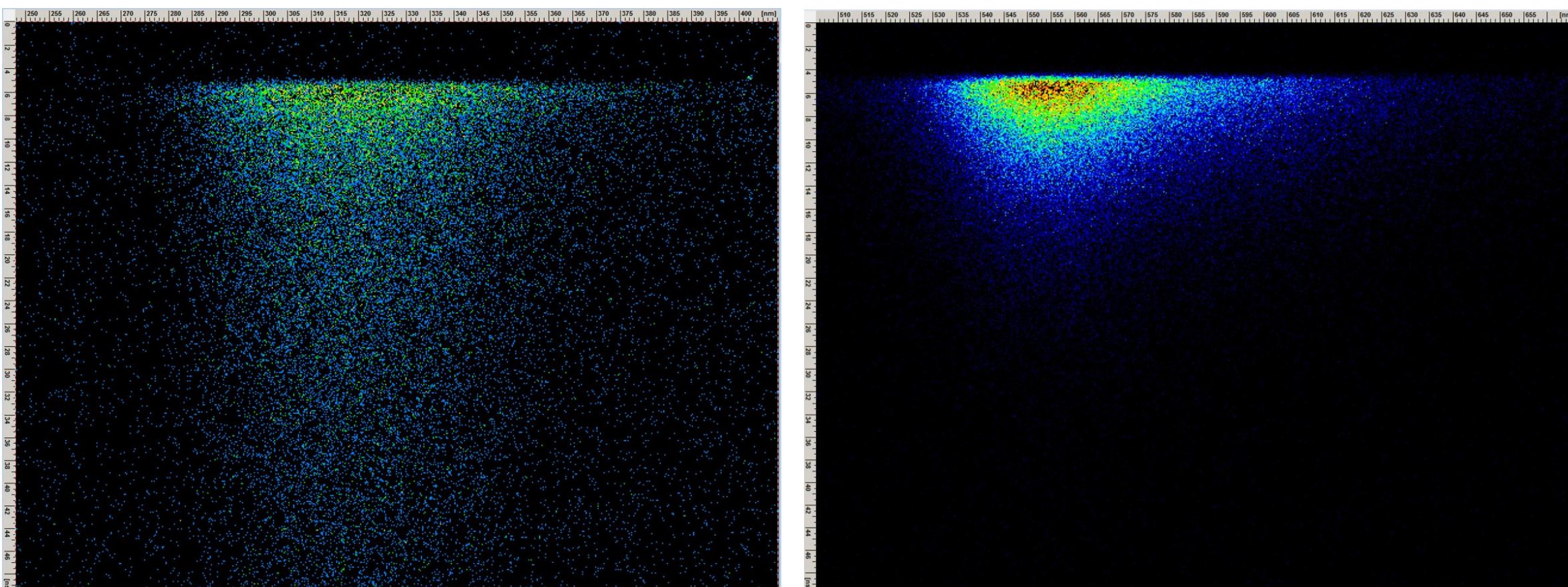


Fig. 3: Streak images of pure CsI (left – accumulation time 30 min) and rhodamine 6G in methanol (right – accumulation time 10 min)

Future works

Future works will focus on measuring single crystals of CsI and BaF₂ (especially the very fast component on 223 nm) to compare them with the literature. Furthermore, we will improve the system with motorized x-y-tables for the optics to simplify the adjustment of the optical pathway of light to enhance the signal strength while measuring. Additionally, the development of new scintillation materials and testing the properties will be a task for the future.

Acknowledgement

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References

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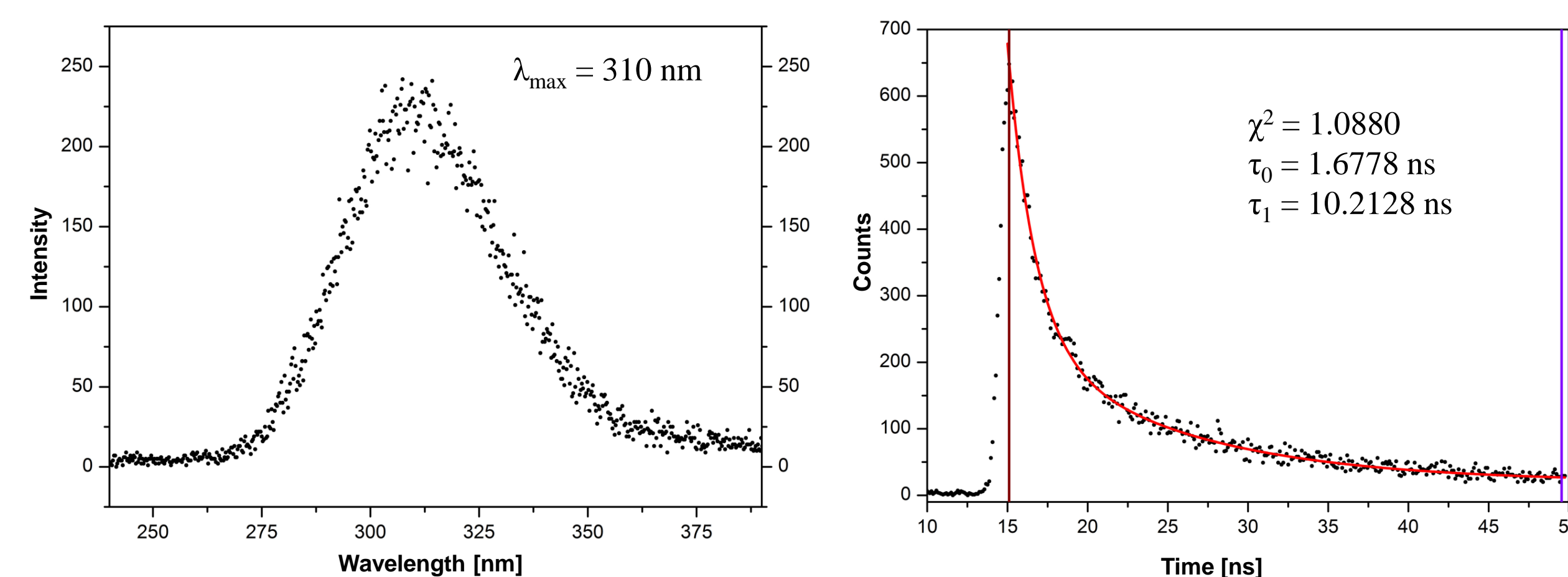


Fig. 4: Emission spectrum and fitting results of X-ray induced fluorescence of pure CsI as 150 mg pellet

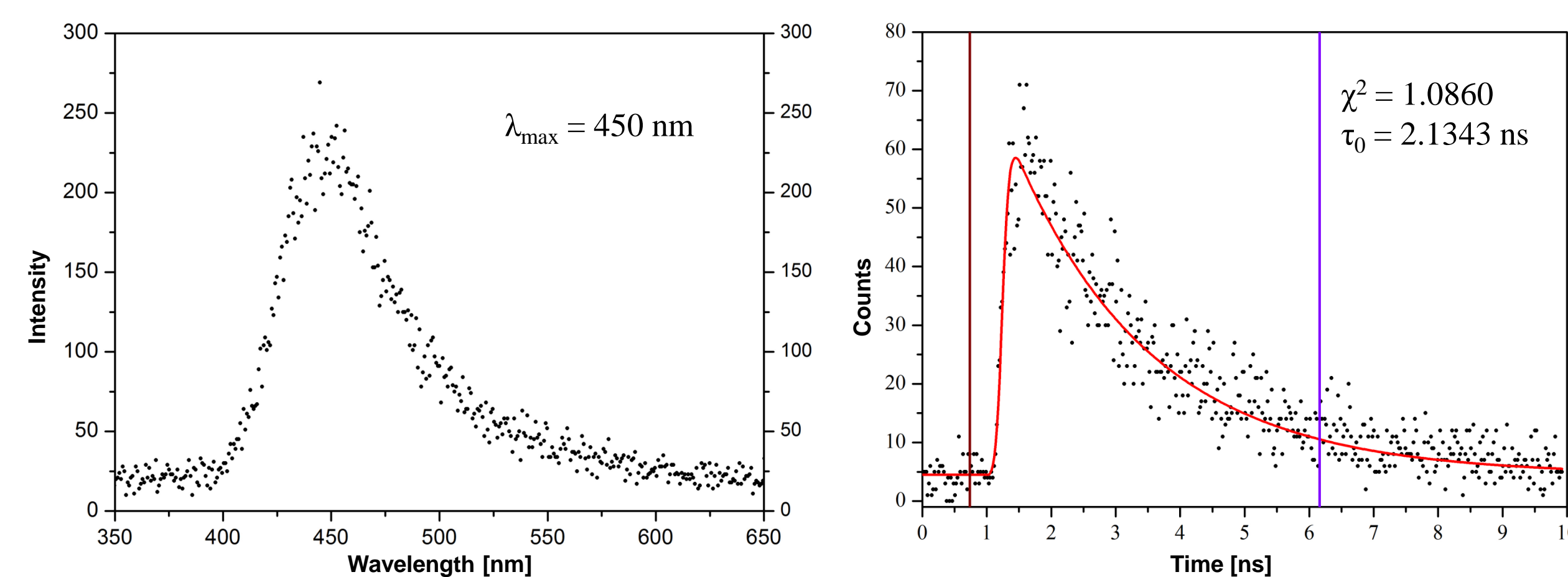


Fig. 5: Emission spectrum and fitting results of X-ray induced fluorescence of anthracene as 90 mg pellet (accumulation time 7 hours)

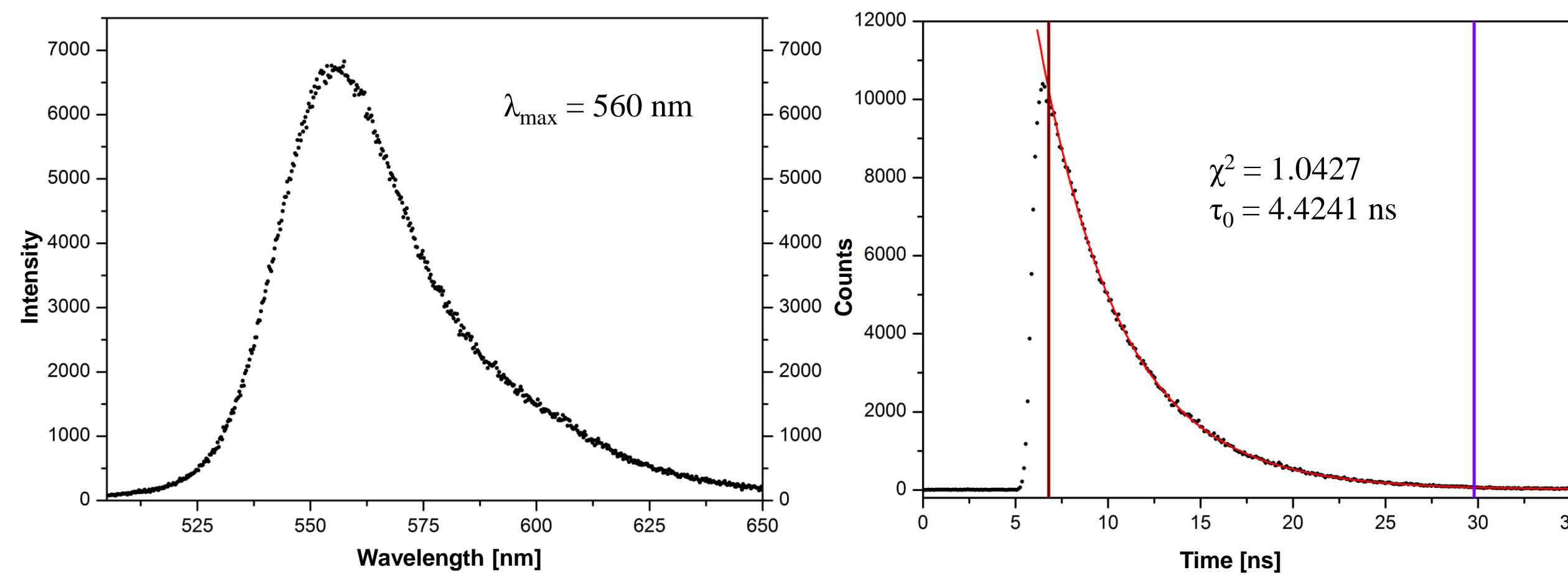


Fig. 6: Emission spectrum and fitting results of laser ($\lambda = 440$ nm) induced fluorescence of rhodamine 6G in methanol