Exercise 1 week 4

You want to measure the optical decay of a quantum dot sample. For this purpose you are using a Silicon pin photodiode which you hook up to a 50 Ω oscilloscope. The diode has an intrinsic region that is 25 µm long, the diameter of the device is 1 mm and you are applying 5V in reverse bias. You excite the quantum dot with a repetition rate of 170 MHz (period 6 ns) and collect the quantum dot emission on the photodiode. A snapshot of the trace is shown in figure 1.

a) Clearly the decay is biexponential. What is the decay time of the fast and slow component?
b) Based on your knowledge of the response time of the photodiode; do you think these decay times represent a true process or could they be measurement artifacts?
c) How could you improve the measurement?

For these questions you might need some material data which you find on the back.

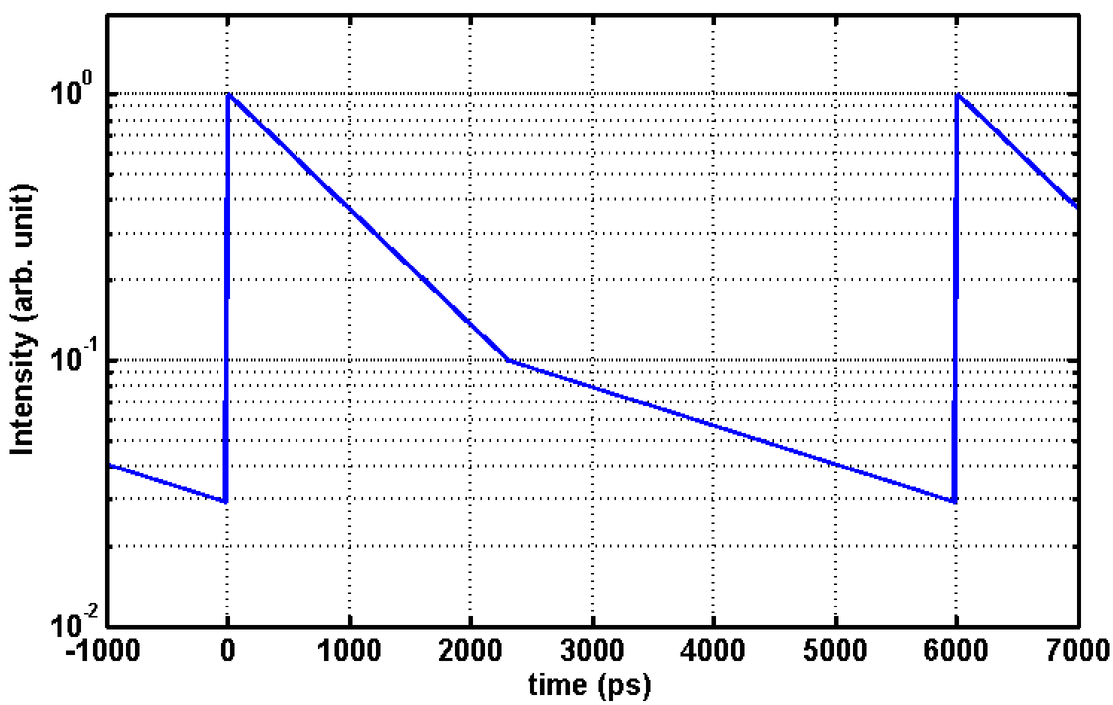
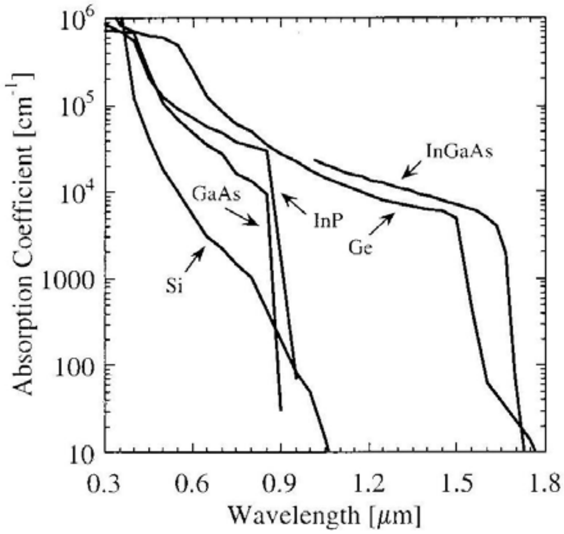
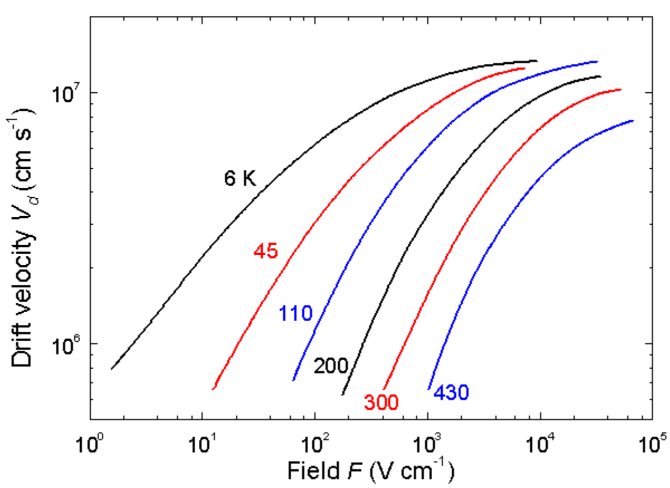


Figure 1

Quantity	Symbol	Si	Ge	GaAs	(Unit)
Crystal structure		D	D	Z	–
Gap: Direct (D) / Indirect (I)		I	I	D	–
Lattice constant	$a_0 =$	5.43095	5.64613	5.6533	Å
Bandgap energy	$E_g =$	1.12	0.66	1.42	eV
Intrinsic carrier concentration	$n_i =$	1.0×10^{10}	2.0×10^{13}	2.0×10^{6}	cm^{-3}
Effective DOS at CB edge	$N_c =$	2.8×10^{19}	1.0×10^{19}	4.4×10^{17}	cm^{-3}
Effective DOS at VB edge	$N_v =$	1.0×10^{19}	6.0×10^{18}	7.7×10^{18}	cm^{-3}
Electron mobility	$\mu_n =$	1500	3900	8500	$cm^2/(Vs)$
Hole mobility	$\mu_p =$	450	1900	400	$cm^2/(Vs)$
Electron diffusion constant	$D_n =$	39	101	220	cm^2/s
Hole diffusion constant	$D_p =$	12	49	10	cm^2/s
Electron affinity	$\chi =$	4.05	4.0	4.07	V
Minority carrier lifetime	$\tau =$	10^{-6}	10^{-6}	10^{-8}	s
Electron effective mass	$m_e^* =$	0.98 m_e	1.64 m_e	0.067 m_e	–
Heavy hole effective mass	$m_{hh}^* =$	0.49 m_e	0.28 m_e	0.45 m_e	–
Relative dielectric constant	$\varepsilon_r =$	11.9	16.0	13.1	–
Refractive index near E_g	$\bar{n} =$	3.3	4.0	3.4	–
Absorption coefficient near E_g	$\alpha =$	10^3	10^3	10^4	cm^{-1}



Handbook of Optical Constants of Solids, edited by Edward D. Palik, (1985), Academic Press NY.



Drift velocities for Silicon, assume electrons and holes have the same velocity