Design of silicon PIN photodetector

Design a silicon PIN photodetector, which is used to detect light from a He-Ne laser emitting light at a wavelength of 632.8 nm. The circular shaped PIN diode has a thin top p^+ layer, through which light is incident and a thick n^+ bottom layer. The I-layer, which is a lightly doped n-type region of thickness Wis sandwiched between the two heavily doped regions. The light generated current (I_L) can be assumed to be due to carriers generated in the I-layer and within a minority carrier diffusion length on the n^+ side.

The PIN diode is reverse biased by applying a voltage V_r, which is sufficiently high to ensure that the I- layer is fully depleted and the generated carriers (both electrons and holes) flow at saturation velocity (v_{sat}) throughout the I- layer. This is to ensure a low transit time (τ_t) and a high frequency of operation. The critical electric field (E_c) required to reach v_{sat} can be taken to be $E_c = v_{sat} / \mu$, where μ is mobility. Neglecting the transit time delay due to diffusion in the heavily doped regions, τ_t can now be expressed as $\tau_t = W/v_{sat}$.

The properties of the p^+, n and n^+ regions are given below:

Property	**p^+**	**n**	**n^+**
Doping conc. (/cm^3)	10^{20}	10^{14}	10^{19}
Thickness (µm)	0.2	To be designed	500
Electron mobility (cm^2/V-s)	80	1300	100
Hole mobility (cm^2/V-s)	50	400	60
Minority carrier lifetime (µs)	10^{-3}	10	10^{-2}
Diode diameter (µm)	To be designed		

The required specifications of the PIN diode are given in the following table. Design a thickness of the I-layer and the diameter of the diode (*d*) to satisfy the specifications. The diode diameter must be at least 75µm in order to easily align it with the light from an optical fibre. Fill up the expected parameters of the designed diode also in the same table.

Parameters	**Required specifications**	**Expected valueat 300 K with** **W =** ***d* =**
Dark current	< 1 pA	
Responsivity	> 0.45 A/W	
Capacitance	< 100 fF	
Transit time	< 100 ps	
V_r (minimum)	--	
V_r (maximum)	--	

Some data for T = 300 K: For Silicon: $n_i = 10^{10}$ cm^{-3}; $\varepsilon_r = 11.9$; absorption coefficient (α) =**3×10^3 /cm** at 632.8 nm; **$v_{sat} = 1 \times 10^7$ cm/s** for both electrons and holes; critical electric field for avalanche breakdown = 2×10^5 V/cm; Also kT = 0.026 eV; $\varepsilon_o = 8.85 \times 10^{-14}$F/cm; hc = 1.24 eV-µm.