

Physics of Semiconductors (8)

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LED paradox (?)

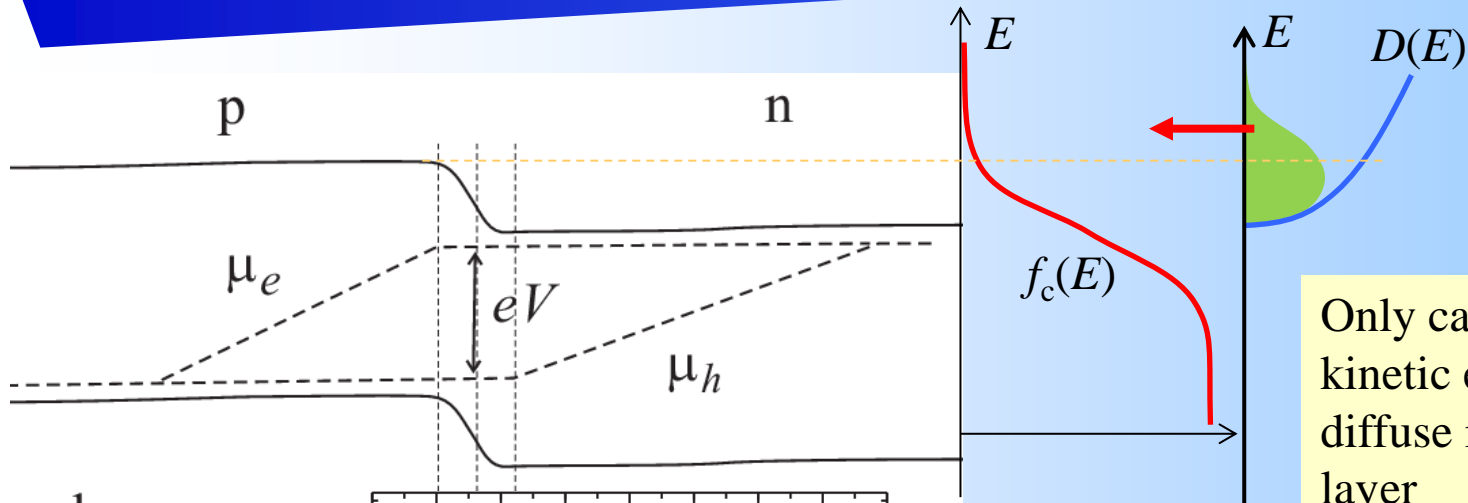


$$\frac{h}{\lambda} = eV \quad \lambda(\mu\text{m})E(\text{eV}) = 1.24$$

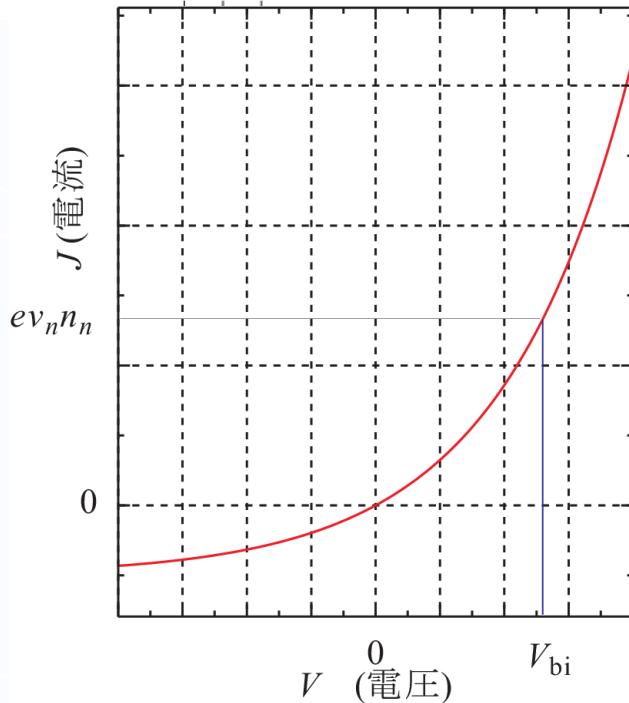
2.4 V: 0.517 μm Green!

Blue: 0.45 μm -> 2.76eV

LED paradox (?)

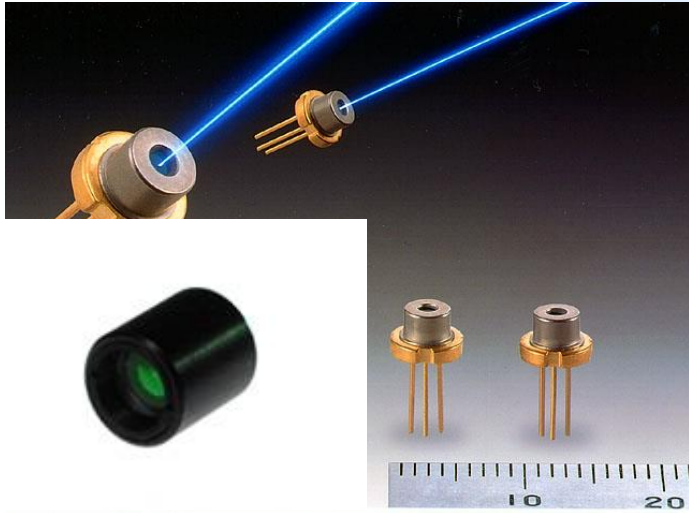


Only carriers with high kinetic energies can diffuse into the other layer

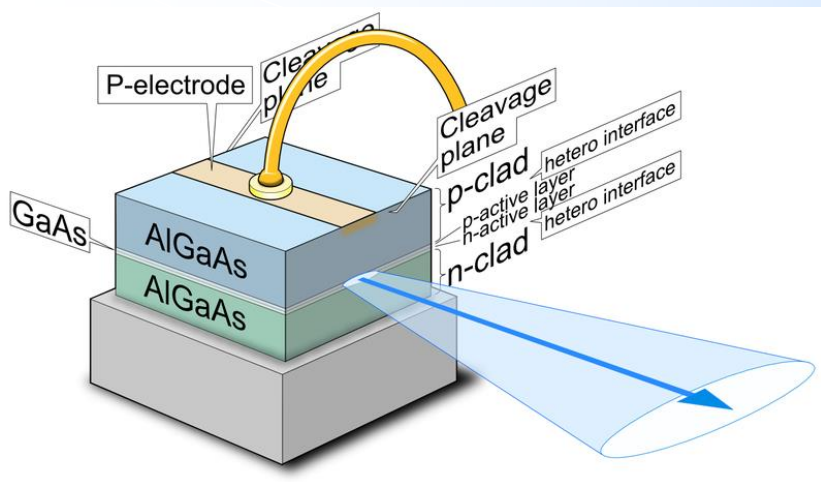


I-V characteristics: observation of distribution function
Can be used as a thermometer.

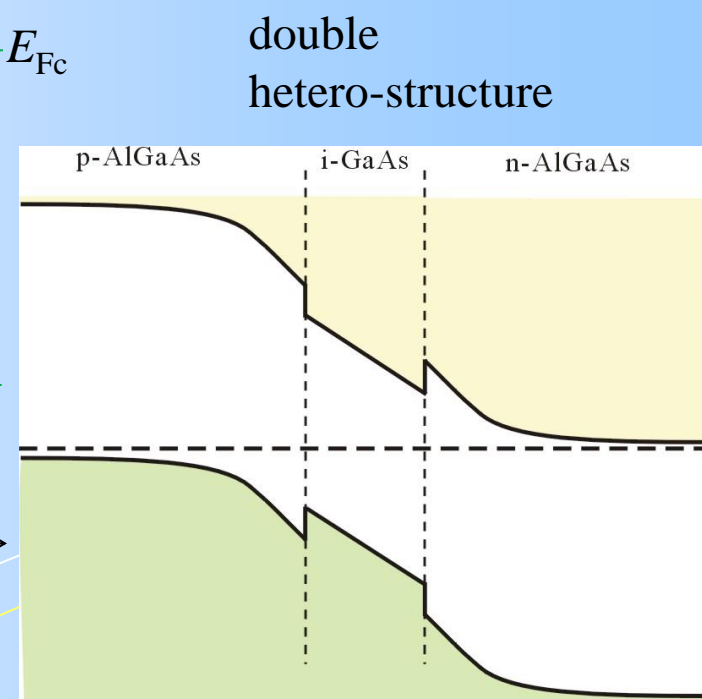
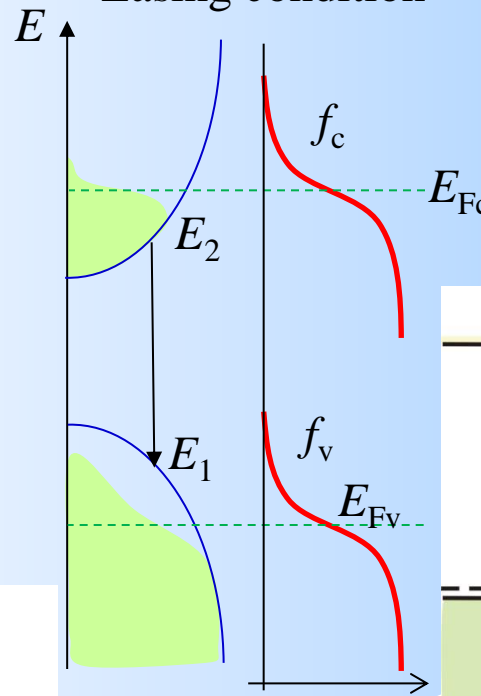
Laser diodes (LDs)



blue LD ((In,Ga)N well material)



Lasing condition $E_{F_c} - E_{F_v} > E_2 - E_1$



$I(z) = I_0 \exp(-\alpha' z)$ $\alpha' < 0$

Waveguide in LDs

Fabry-Pérot resonator

$$m_j \frac{\lambda}{\bar{n}_2} = 2L$$

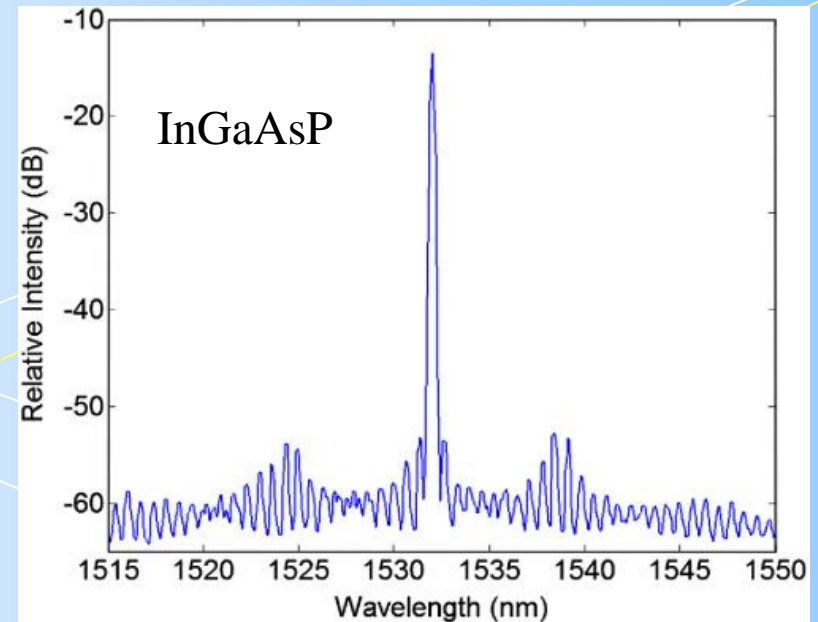
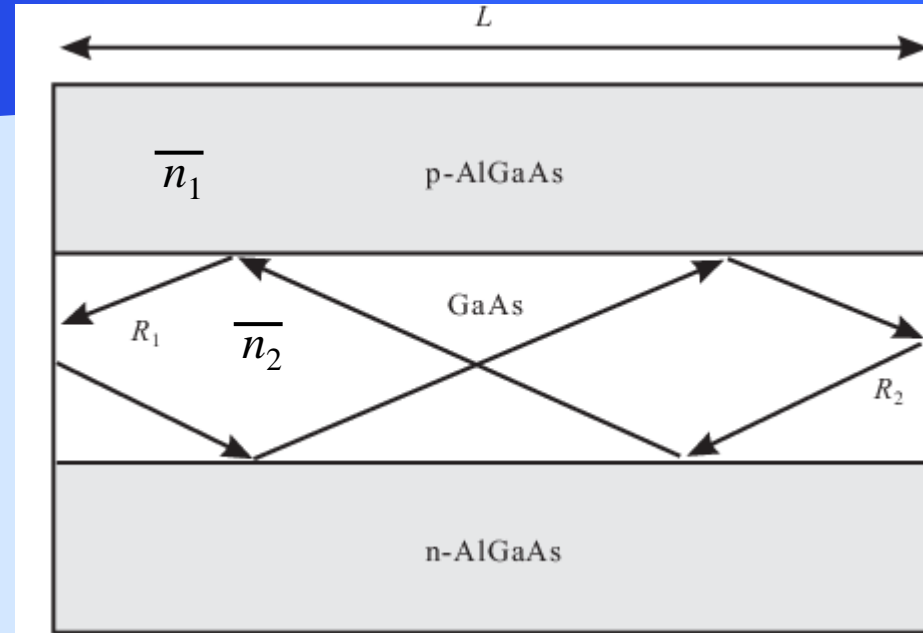
$$\Delta\lambda = \frac{\lambda^2}{2L\bar{n}}, \quad \Delta\nu = \frac{c}{2L\bar{n}}$$

$$I(z) = I_0 \exp(-\alpha'z) = I_0 \exp((g - \alpha)z)$$

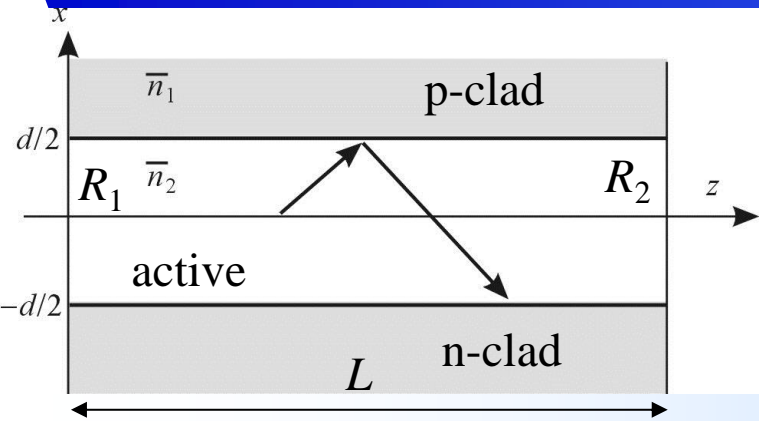
$$R_1 R_2 \exp[(g - \alpha)2L] > 1$$

$$g_{\text{th}} = \alpha + \frac{1}{L} \ln \left(\frac{1}{R_1 R_2} \right)$$

critical angle $\theta_c = \arcsin \left[\frac{\bar{n}_1}{\bar{n}_2} \right] \quad \therefore \bar{n}_2 > \bar{n}_1$



Waveguide in LDs



TE mode

$$\left[\frac{\partial^2}{\partial x^2} + \frac{\partial^2}{\partial z^2} - \mu_0 \epsilon_0 \epsilon \frac{\partial^2}{\partial t^2} \right] \mathcal{E}_y = 0.$$

$$\mathcal{E}_y(x, z, t) = A \cos\left(\frac{\kappa d}{2}\right) \exp\left[-\gamma\left(|x| - \frac{d}{2}\right)\right] \exp[i(\omega t - \beta z)] \quad \left(|x| > \frac{d}{2}\right)$$

$$\mathcal{E}_y(x, z, t) = A \cos(\kappa x) \exp[i(\omega t - \beta z)] \quad \left(|x| \leq \frac{d}{2}\right)$$

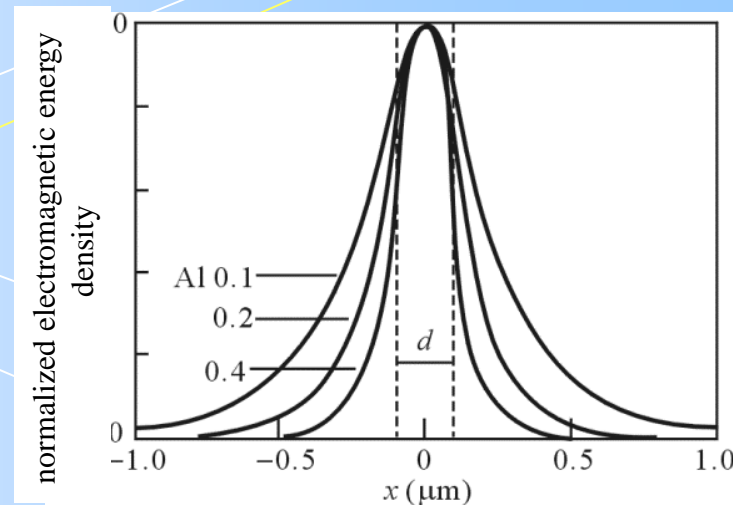
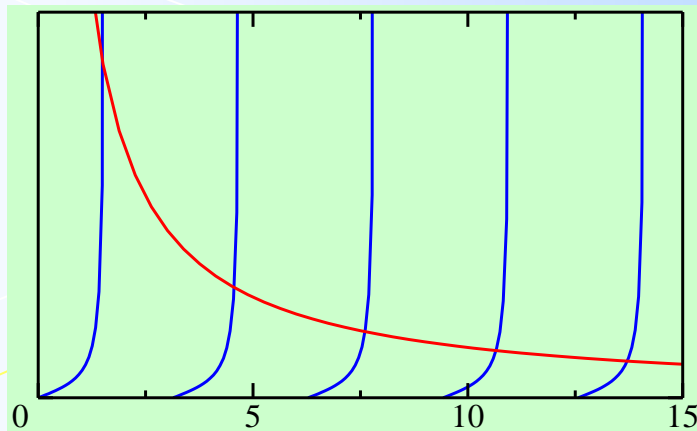
$$\kappa^2 = \mu_0 \epsilon \epsilon_0 \omega^2 - \beta^2 = \bar{n}_2^2 k_0^2 - \beta^2, \quad k_0 = \frac{\omega}{c^* \bar{n}_2}$$

$$\gamma^2 = \beta^2 - \bar{n}_1^2 k_0^2$$

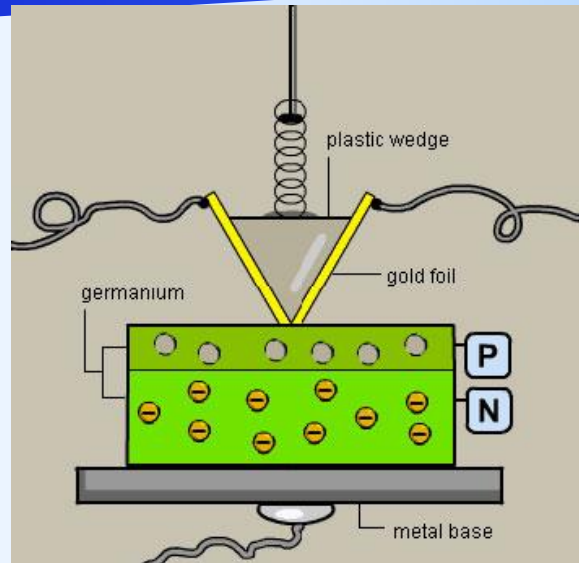
$$\tan\left(\frac{\kappa d}{2}\right) = \frac{\gamma}{\kappa}$$

$$\bar{n}_2 > \bar{n}_1$$

2013/6/4



Invention of Transistor

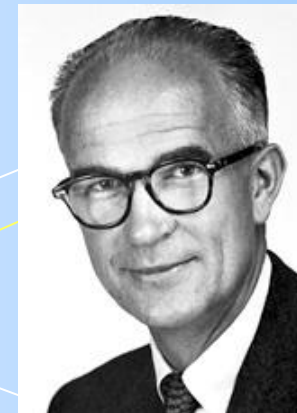


The first point contact transistor

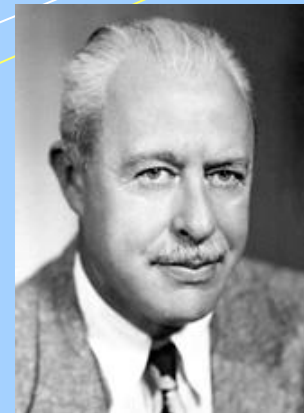
(Dec. 1947,
published Jun. 1948)



John Bardeen

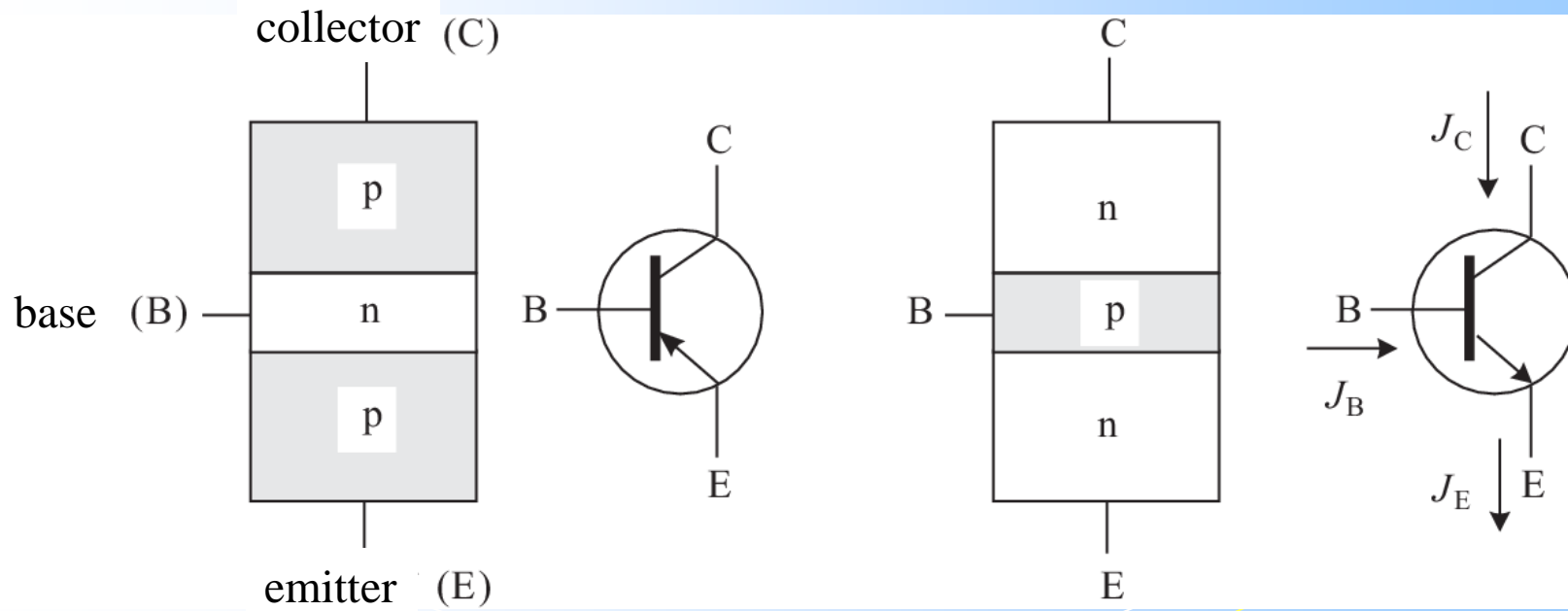


William Shockley

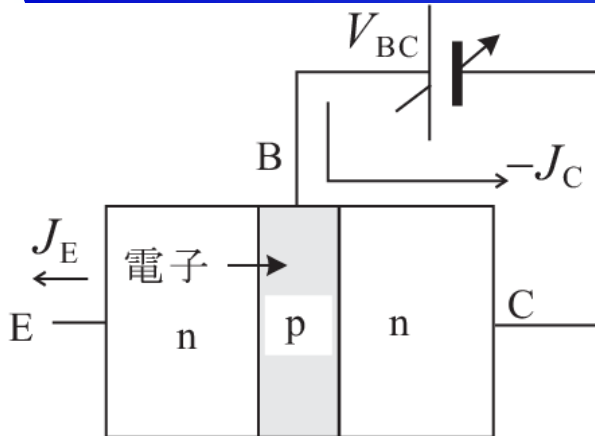


Walter Brattain

Bipolar Junction Transistors (BJT)



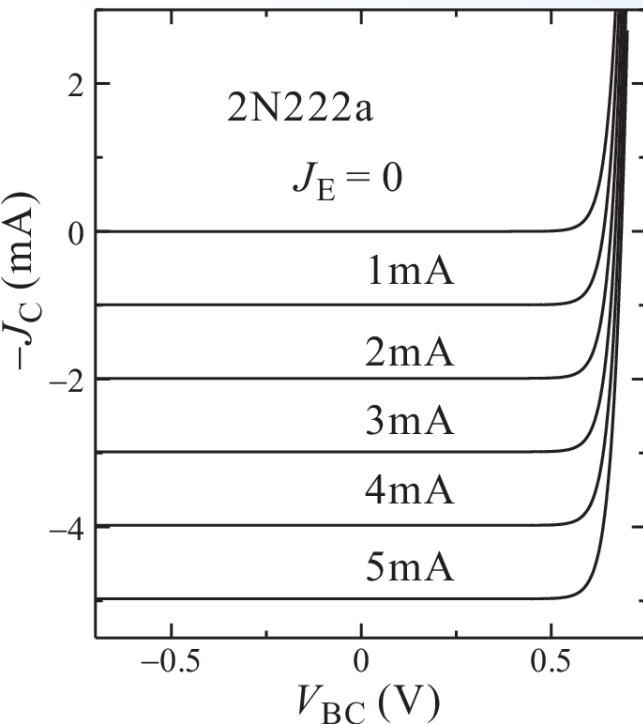
Transistors and Solar Cells



Transistors

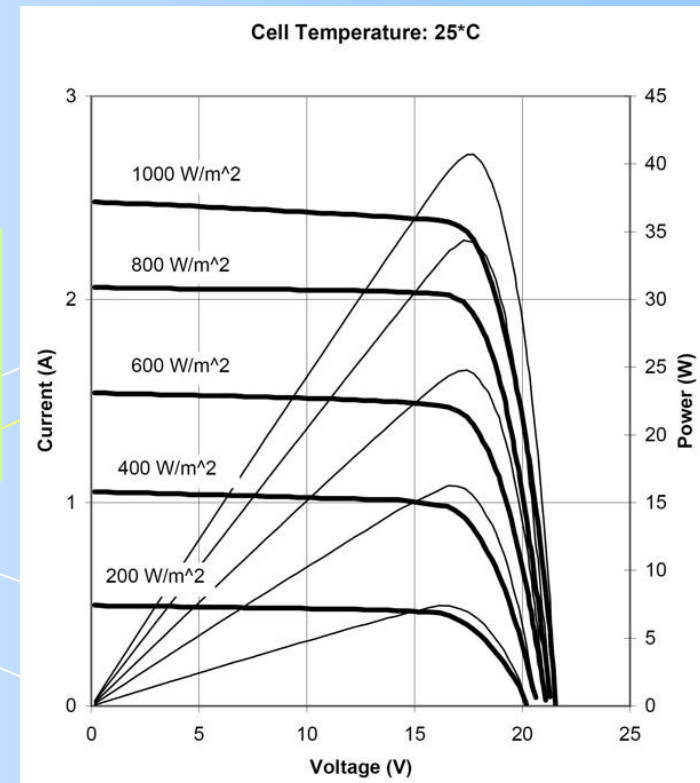
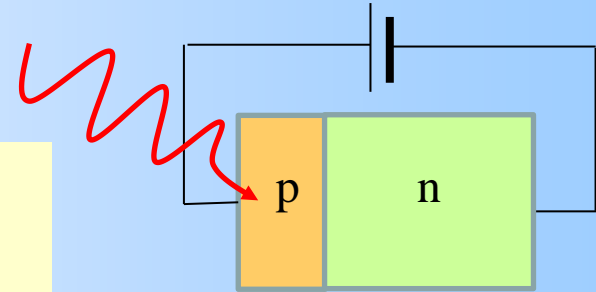
minority carrier injection by another pn junction

-> large reverse current

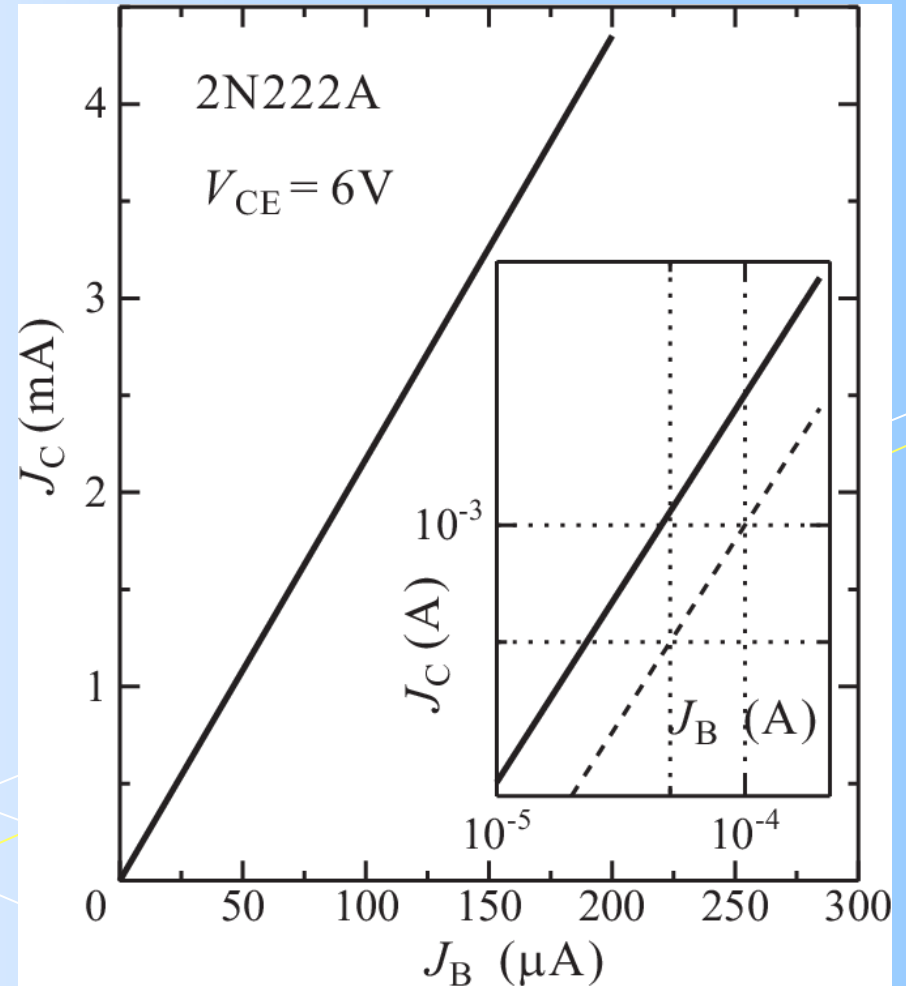
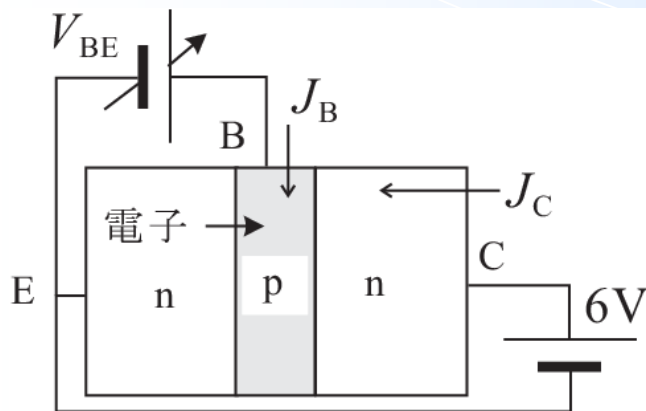
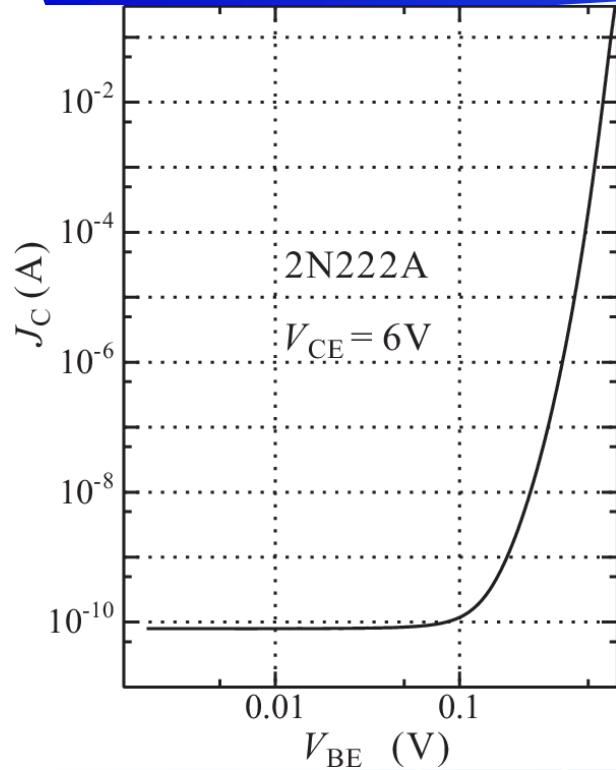


Solar cells

optical injection of minority carriers



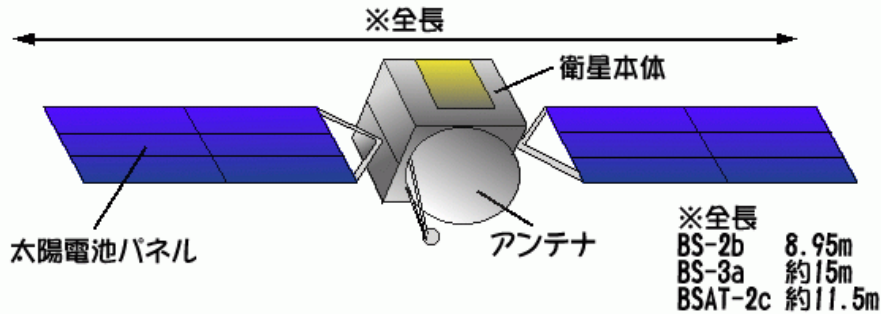
"Current amplification" by BJT



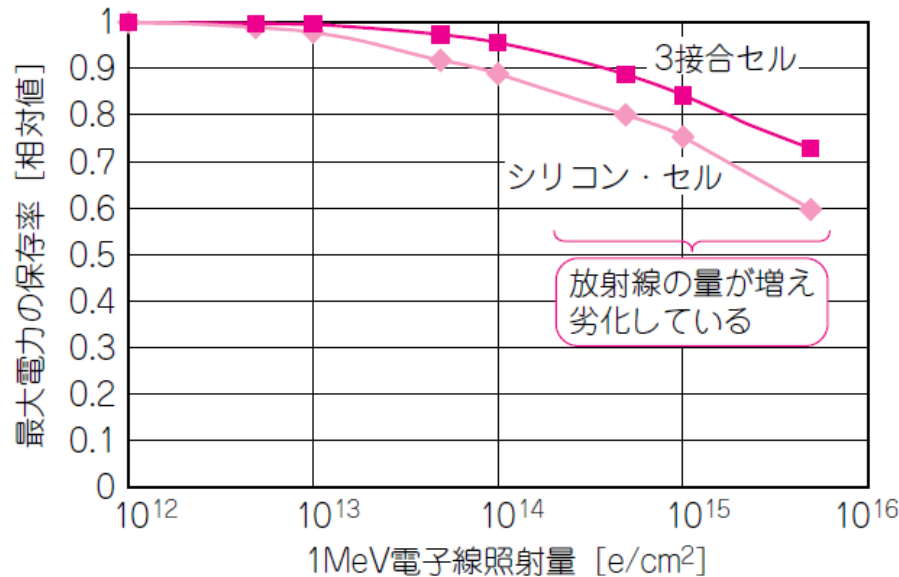
宇宙用太陽電池 - 応用研究の例

BS電源トラブルの例

東経 110° 上空



放送衛星の基本形状と大きさ



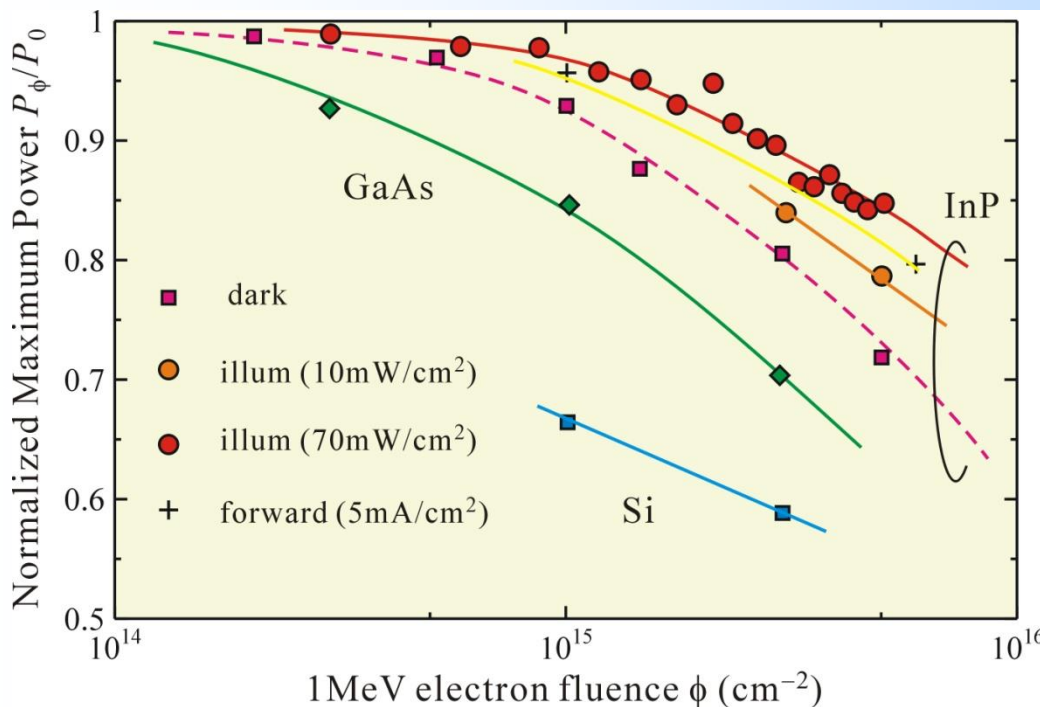
BS-3a では打ち上げ当初から、衛星の不良により所要の発生電力が得られないため、この衛星だけでは 2ch 同時放送しかできず、残り 1ch を古いBS-2b が肩代わり。
初期不良？初期劣化？

食の時期には太陽電池に光が当たらず、放送に必要な電力を賄えないため、放送中断

10年間の被ばく量は1 MeV のエネルギーの電子線に換算しておよそ 1×10^{15} 個/cm² 程度

面積単価より、高効率、低劣化、軽量が重要

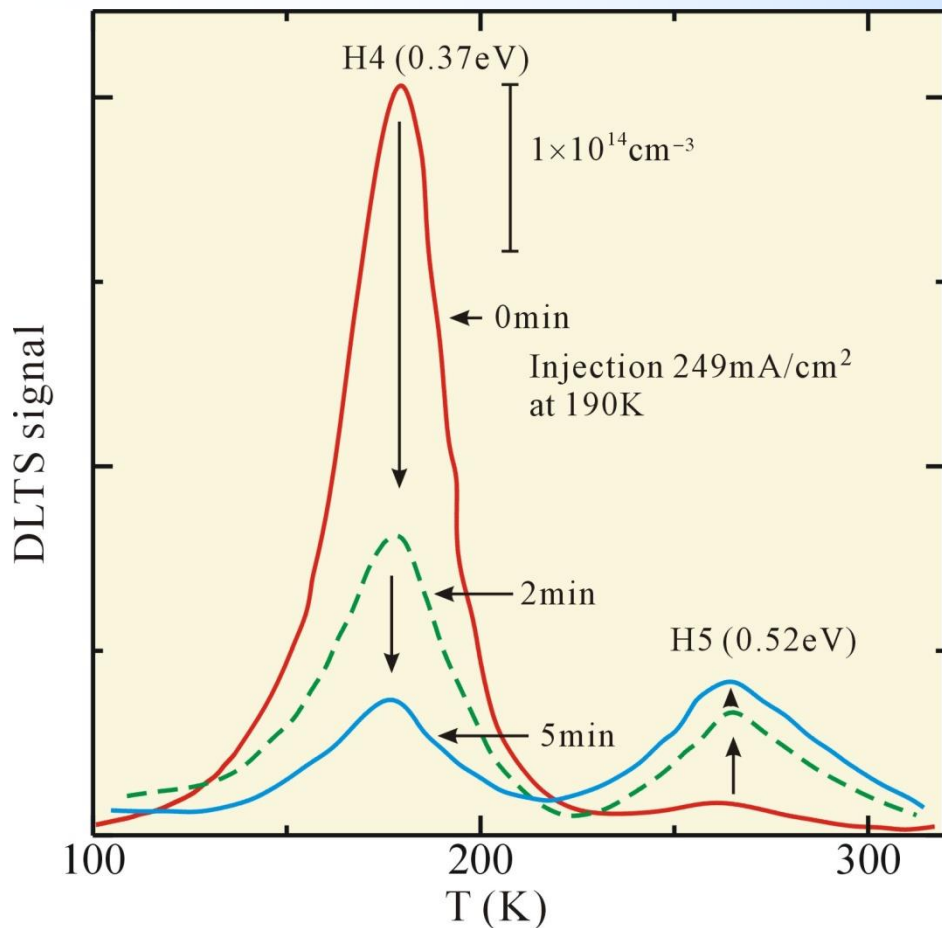
Radiation resistive InP solar cells



	13	IIIA	14	IVA	15	VA	16	VIA
5	10.811		6	12.011	7	14.007	8	15.999
	(He) 2s ² 2p ¹		(He) 2s ² 2p ²		(He) 2s ² 2p ³		(He) 2s ² 2p ⁴	
	B		C		N		O	
	BORON		CARBON		NITROGEN		OXYGEN	
13	26.982		14	28.086	15	30.974	16	32.065
	(Ne) 3s ² 3p ¹		(Ne) 3s ² 3p ²		(Ne) 3s ² 3p ³		(Ne) 3s ² 3p ⁴	
	Al		Si		P		S	
	ALUMINIUM		SILICON		PHOSPHORUS		SULFUR	
12	IIIB							
30	65.409		31	69.723	32	72.64(1)	33	74.922
	(Ar) 3d ¹⁰ 4s ²		(Ar) 3d ¹⁰ 4s ² 4p ¹		(Ar) 3d ¹⁰ 4s ² 4p ²		(Ar) 3d ¹⁰ 4s ² 4p ³	
	Zn		Ga		Ge		As	
	ZINC		GALLIUM		GERMANIUM		ARSENIC	
48	112.411		49	114.818	50	118.710	51	121.760
	(Kr) 4d ¹⁰ 5s ²		(Kr) 4d ¹⁰ 5s ² 5p ¹		(Kr) 4d ¹⁰ 5s ² 5p ²		(Kr) 4d ¹⁰ 5s ² 5p ³	
	Cd		In		Sn		Sb	
	CADMIUM		INDIUM		TIN		ANTIMONY	
							52	127.60(3)
							(Kr) 4d ¹⁰ 5s ² 5p ⁴	
							Te	
							TELLURIUM	

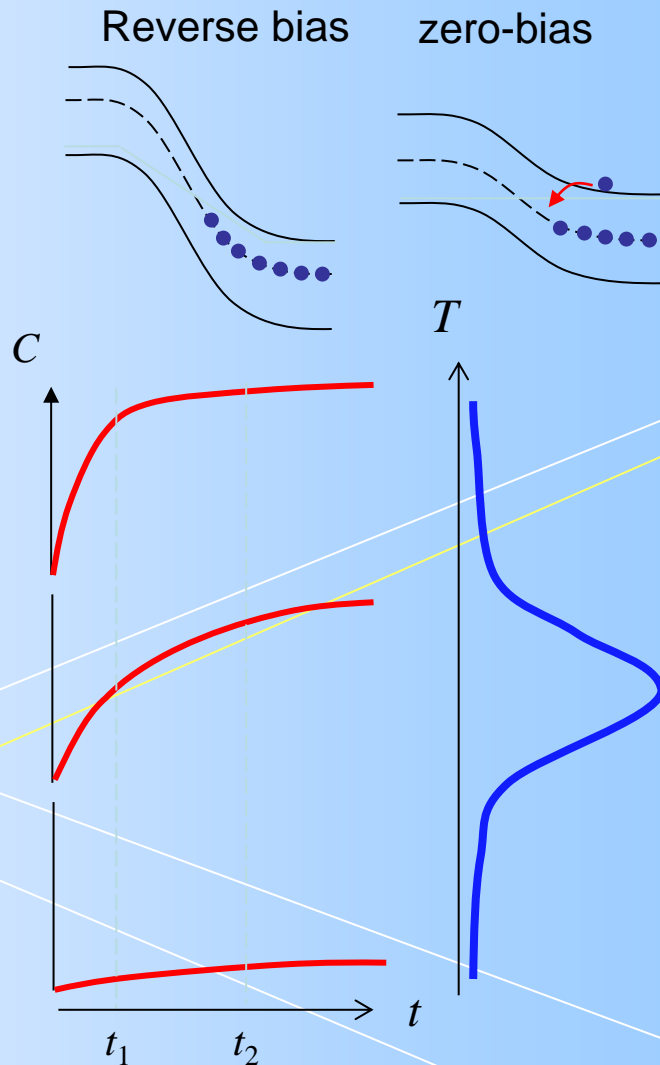
Radiation resistive InP solar cells

deep level transient spectroscopy, DLTS



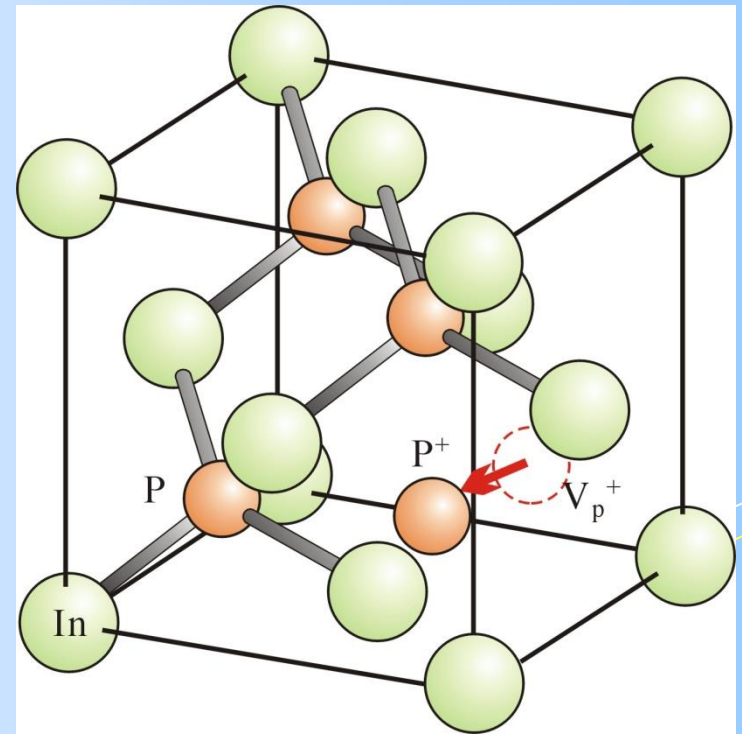
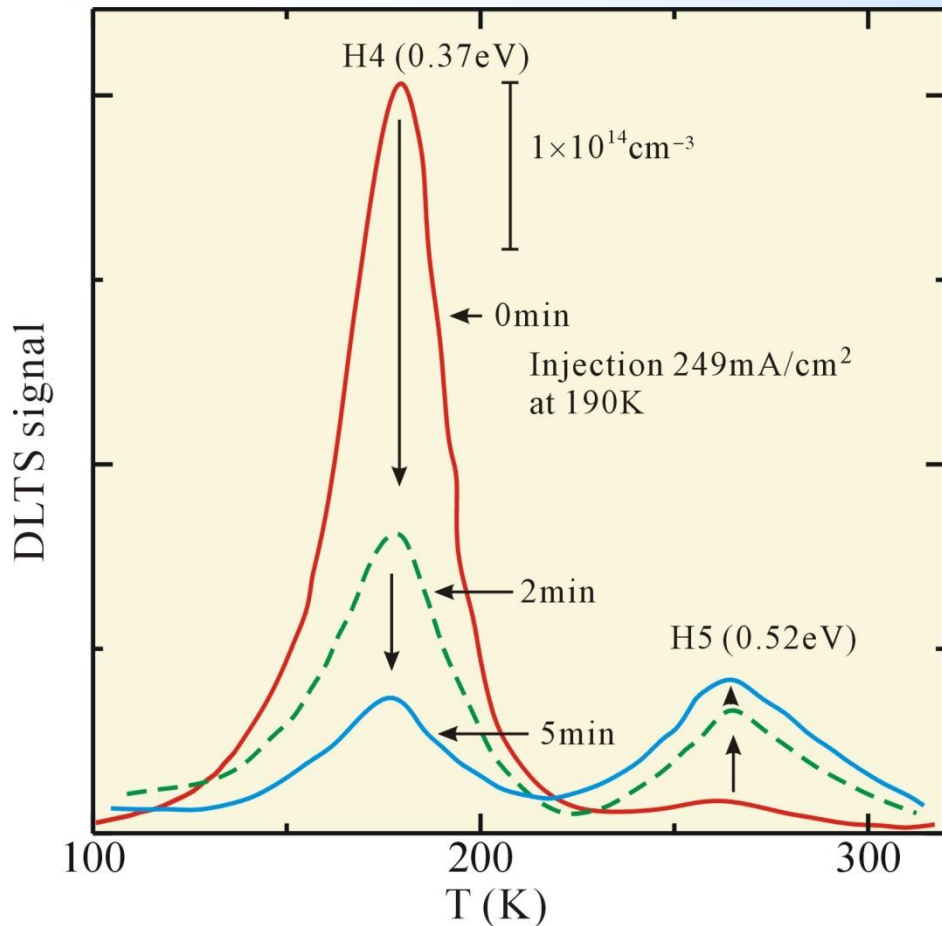
$$\left[\frac{2\epsilon\epsilon_0(V + V_{bi})}{eN_D} \right]^{1/2} \approx w_n$$

depletion layer width



Radiation resistive InP solar cells

deep level transient spectroscopy, DLTS



M. Yamaguchi

2004 Becquerel Prize
2008 Cherry Award

High-efficiency, light-weight cells

Materials with In: similar resistivity to radiation

InGaAs bottom cell
GaAs, InGaAlAs top cell

Film cells on Si

