DESIGN CONSIDERATIONS FOR HEAVILY-DOPED CRYOGENIC SCHOTTKY DIODE VARACTOR MULTIPLIERS

E. Schlecht, F. Maiwald, G. Chattopadhyay, S. Martin, and I. Mehdi

JPL *SWAT* Team

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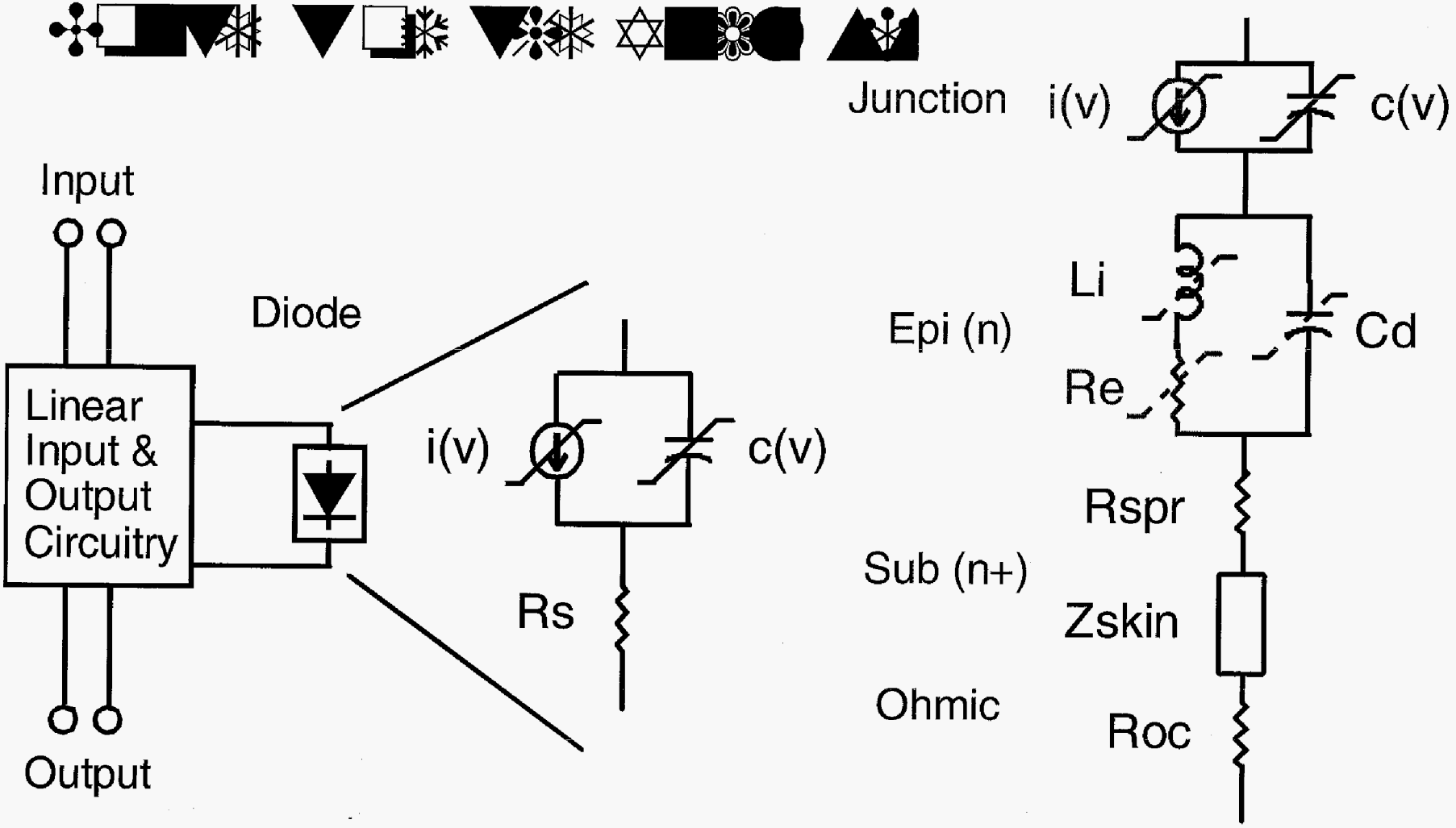
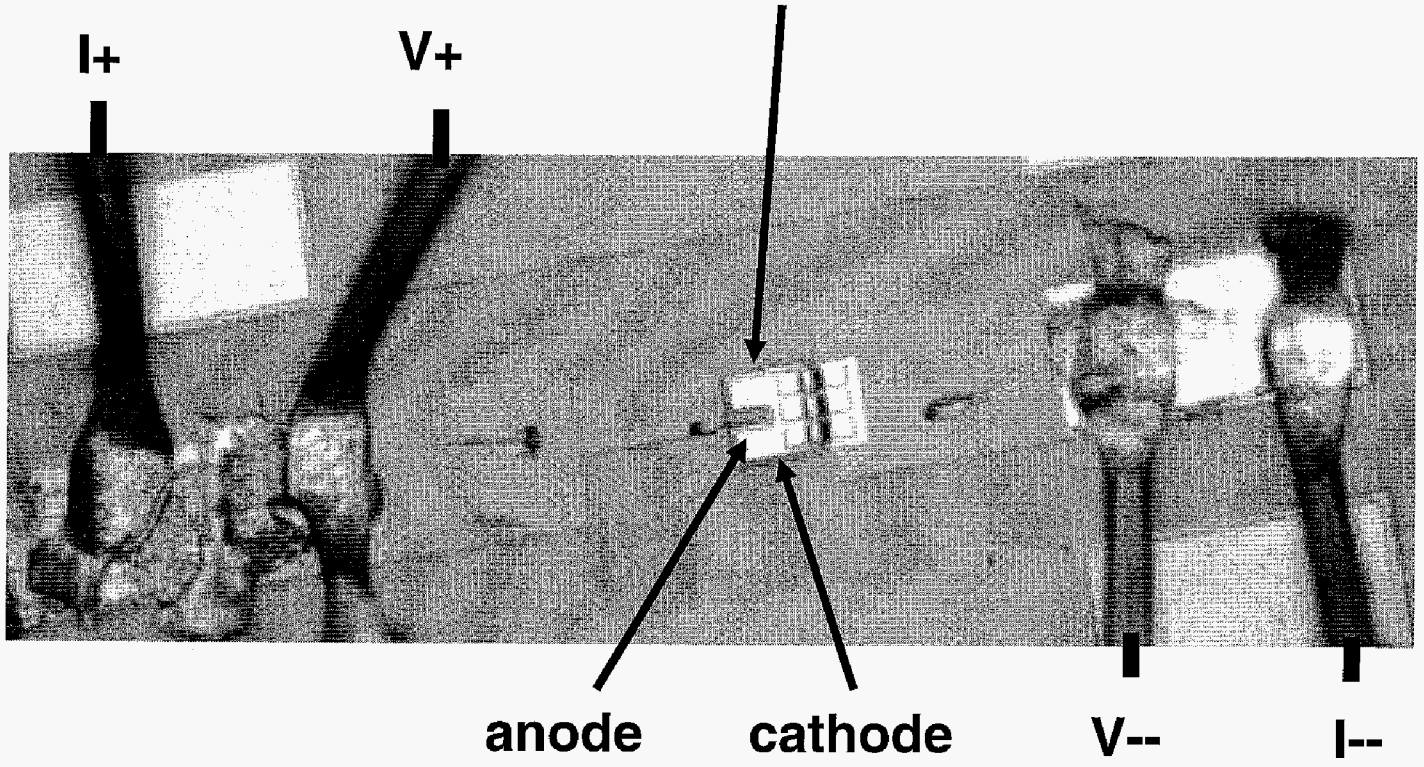


Multiplier Circuit | Simple Diode Model | Complex Diode Model

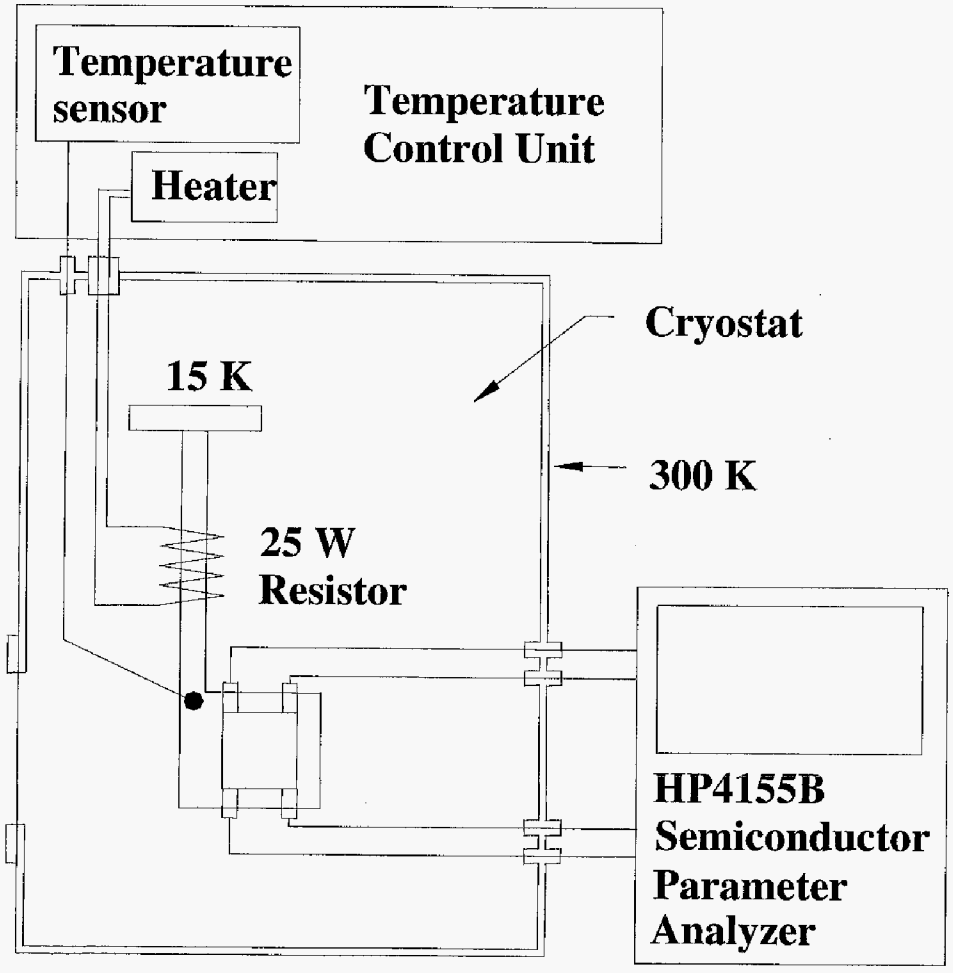
Four Probe Measurement

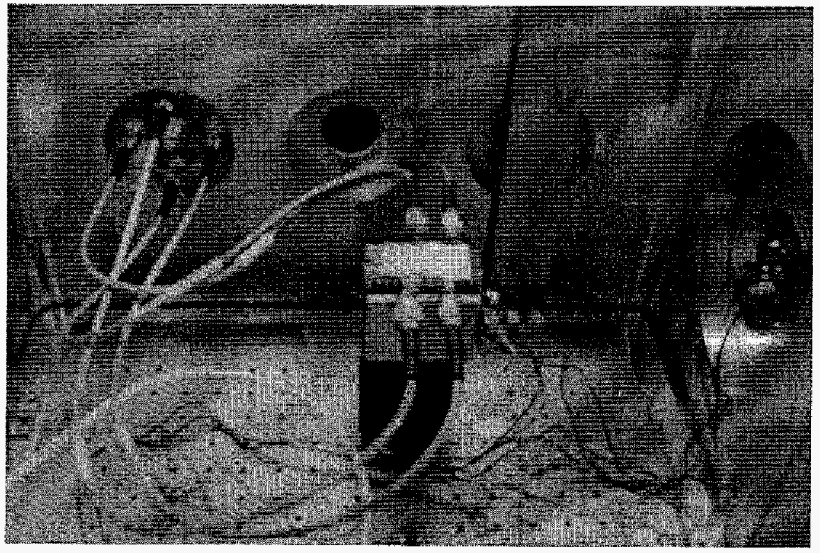
Eliminates effect of series resistance in cabling

3E17 diode, anode size 1.5 x 10.4 μm

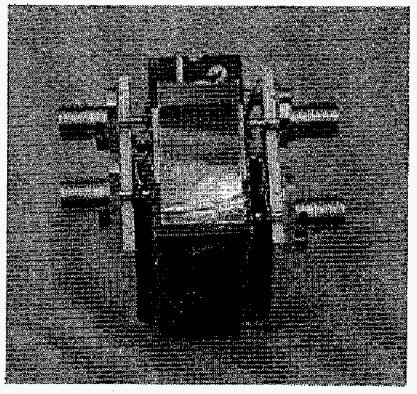


Block Diagram of the Cryostat





Inside of the cryostat



4-probe station with prepared test diode

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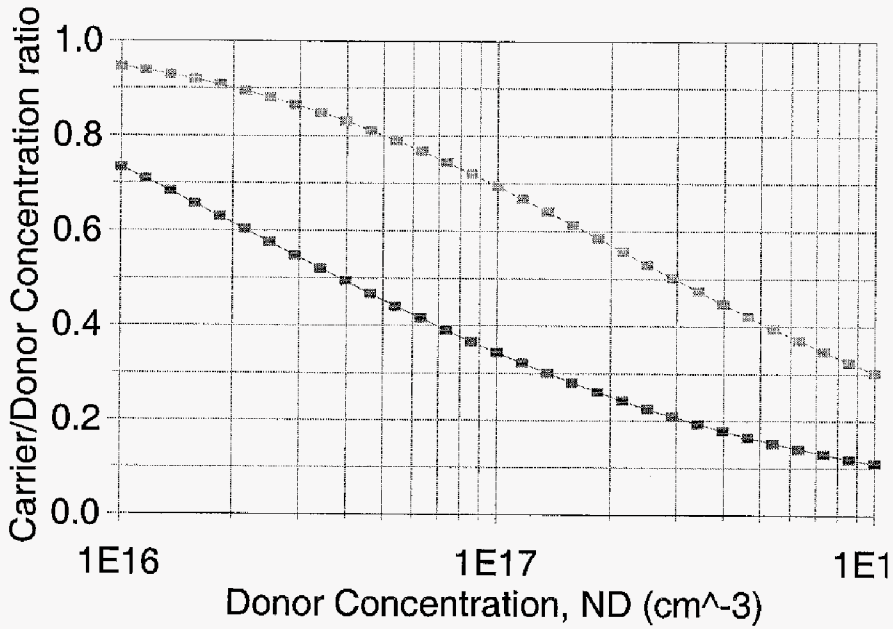
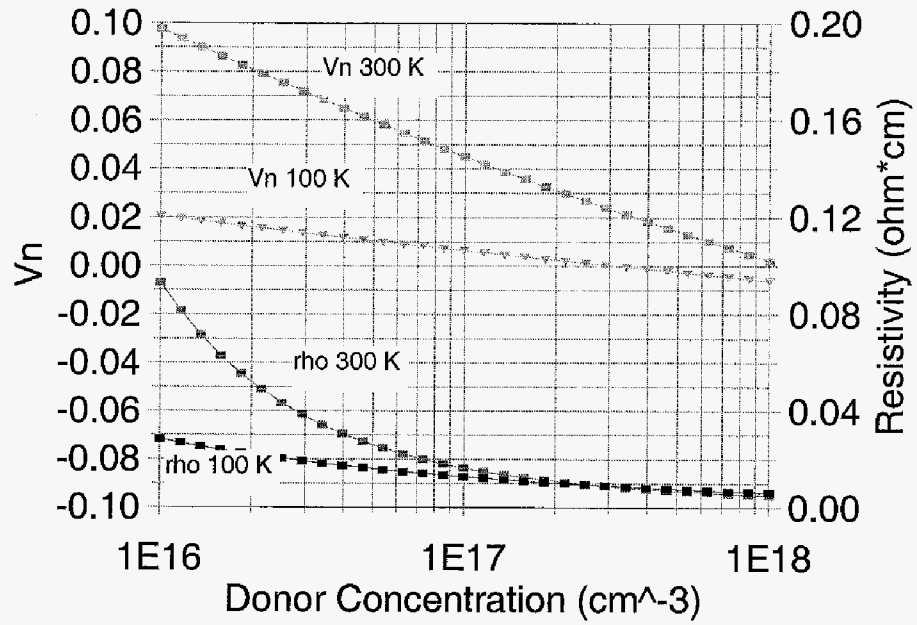
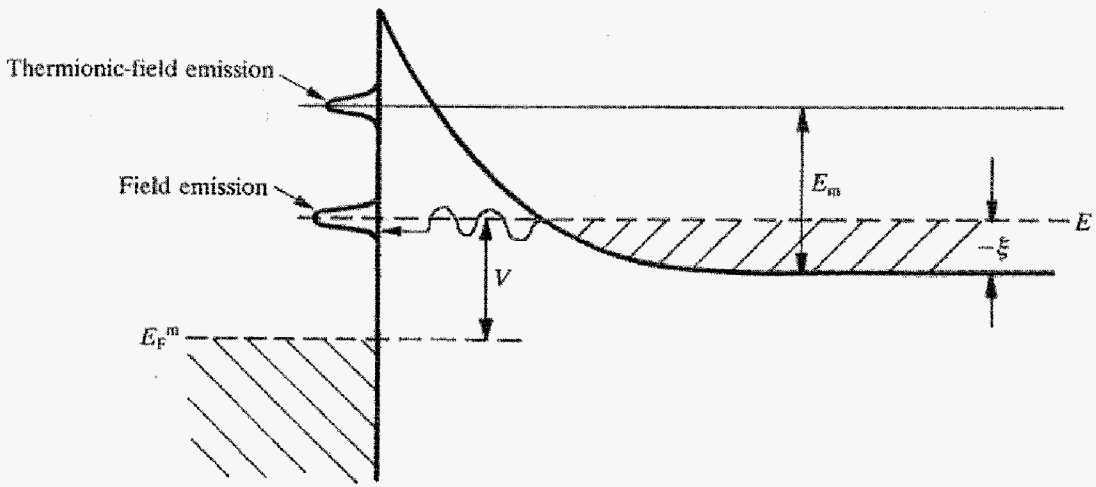
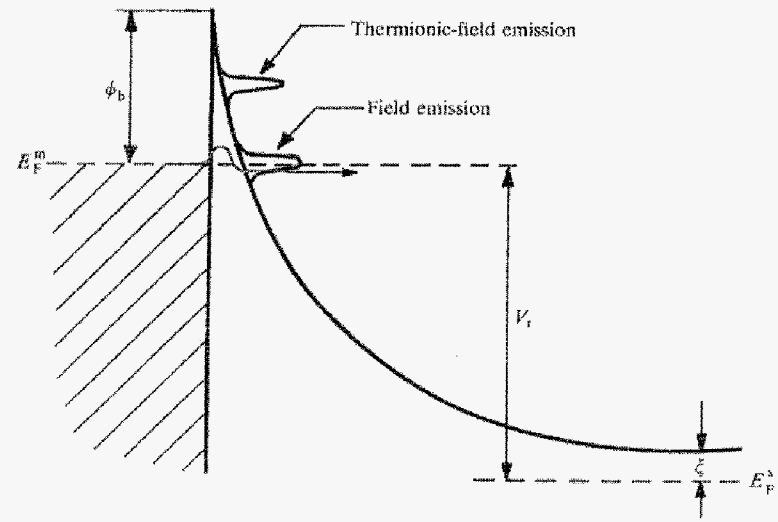




Full Schottky Current Calculation



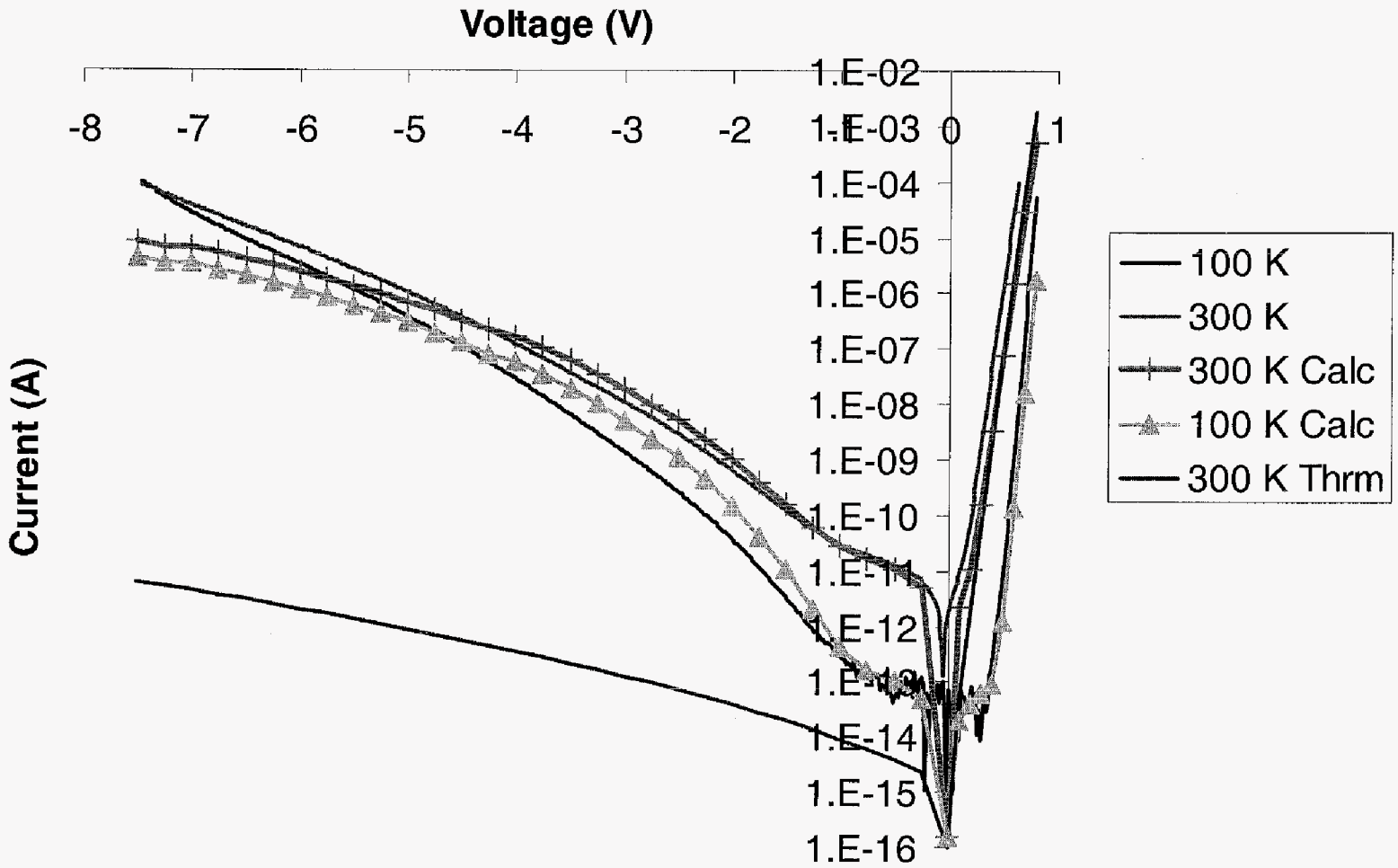
Forward Bias



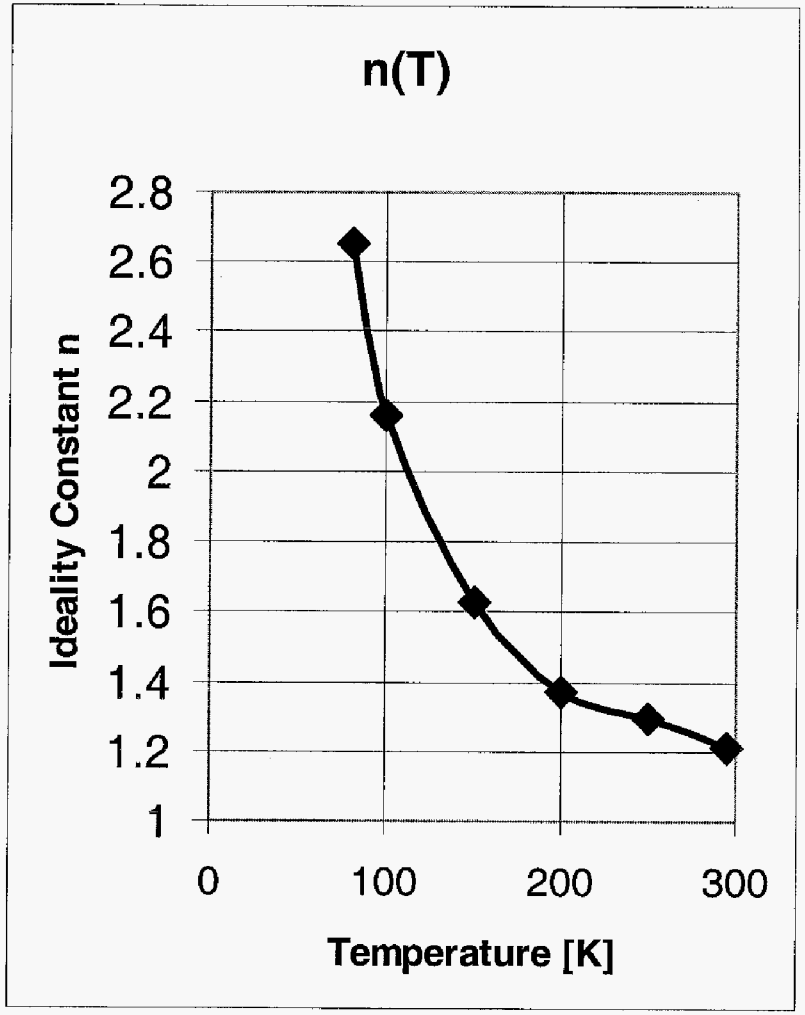
Reverse Bias

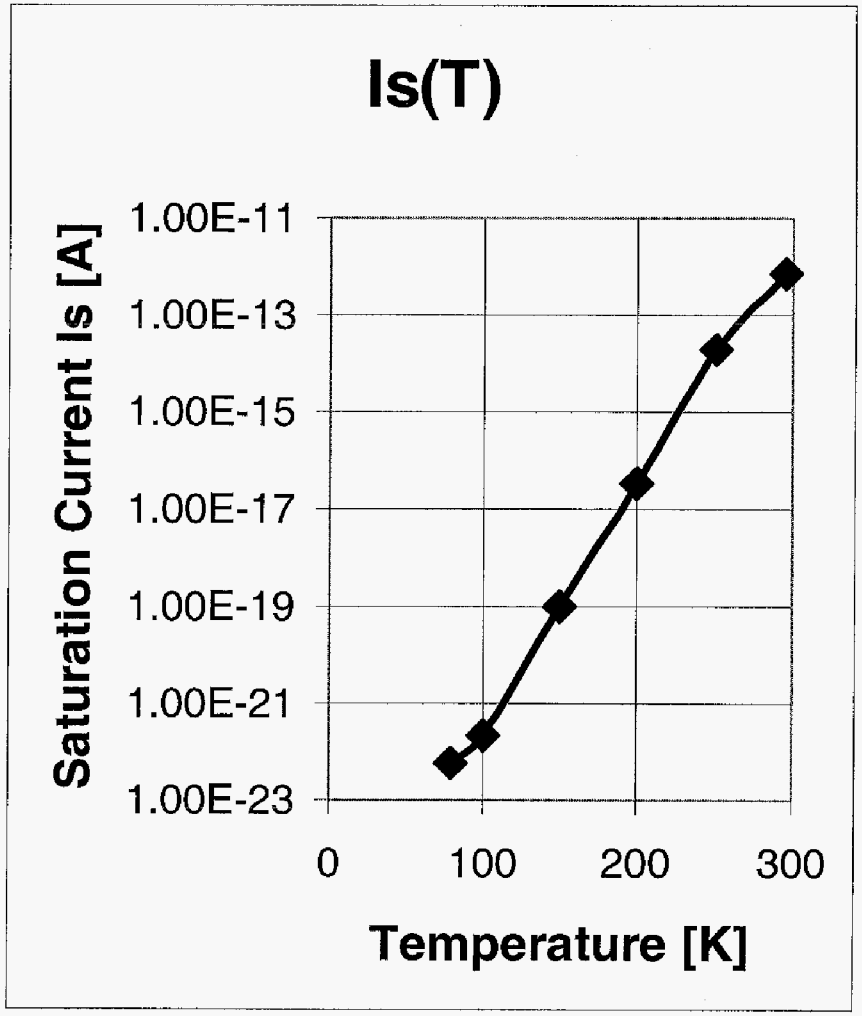
$$J(V) = \frac{4\pi q m^* kT}{h^3} \int_{E_{\min}}^{\infty} T(E_n) \ln\left\{ \frac{1+\exp[(E_{Fm} - E_n)/kT]}{1+\exp[(E_{Fm} + V - E_n)/kT]} \right\} dE_n$$

Current Calculation vs Measurement, ND=3e17

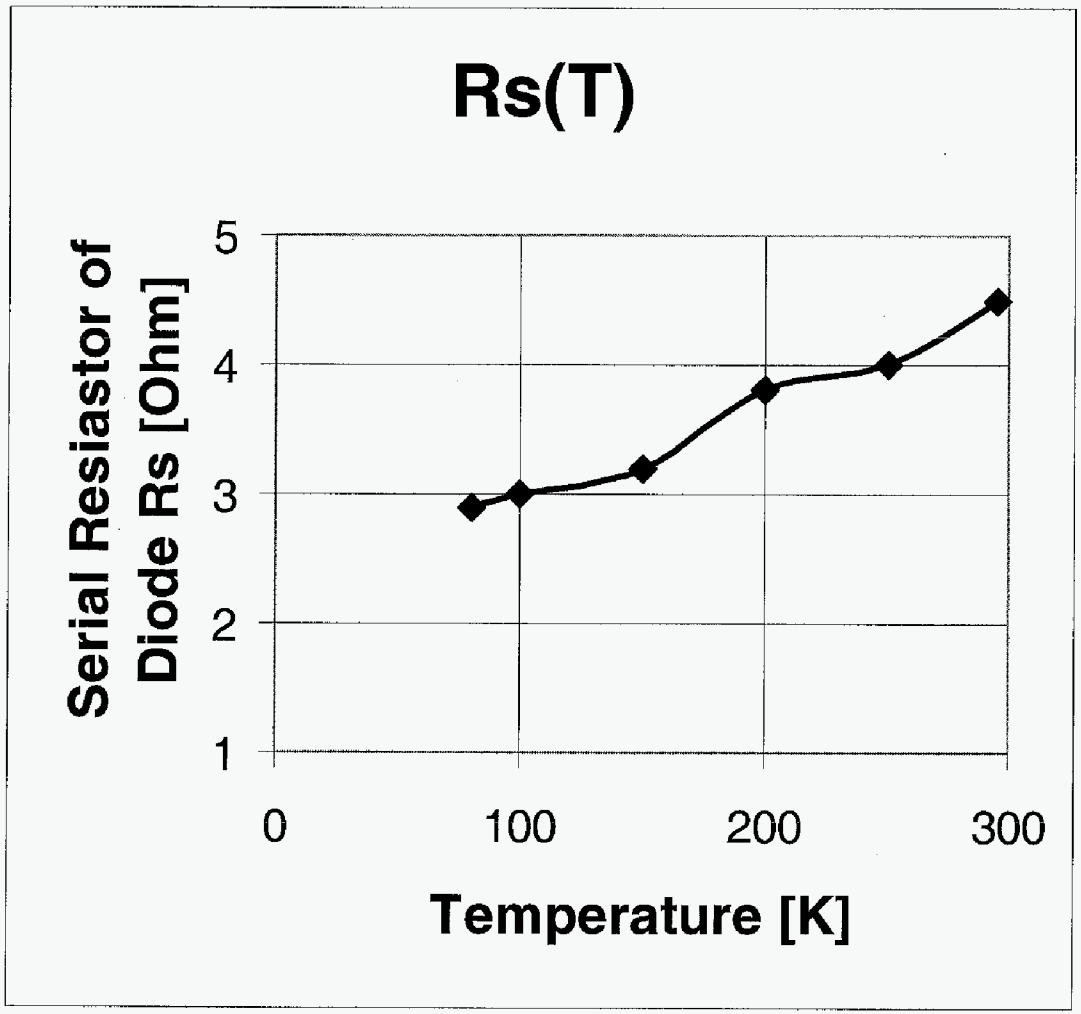


Temperature dependence of the 5E17 diode



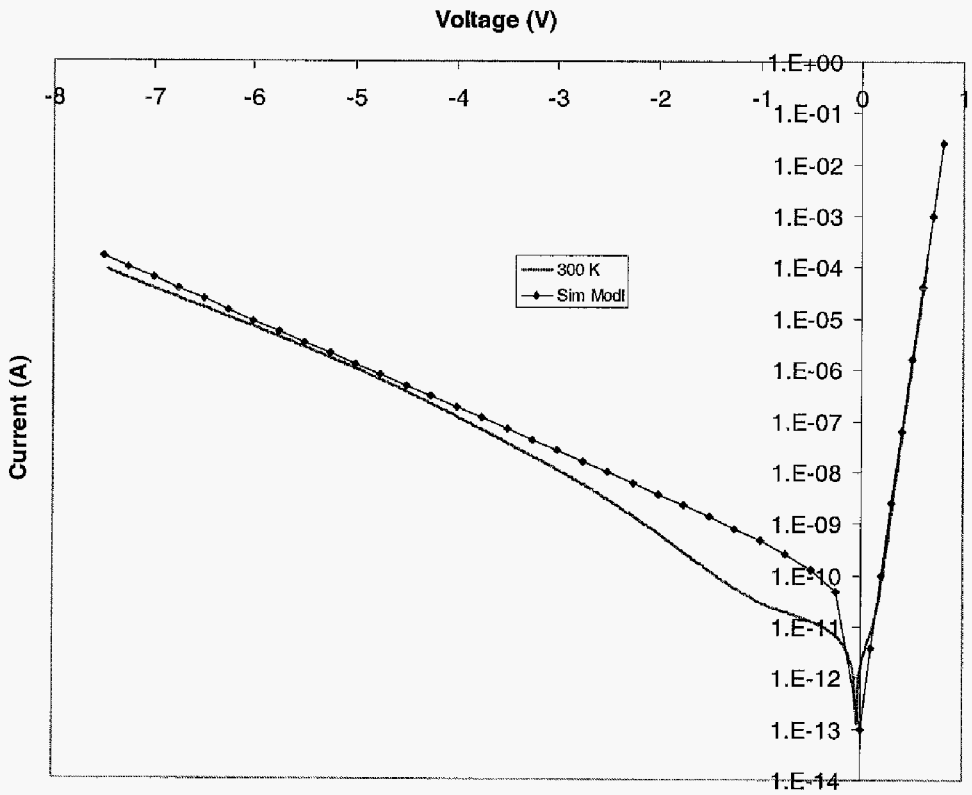


Temperature dependence of the 5E17 diode, cont.

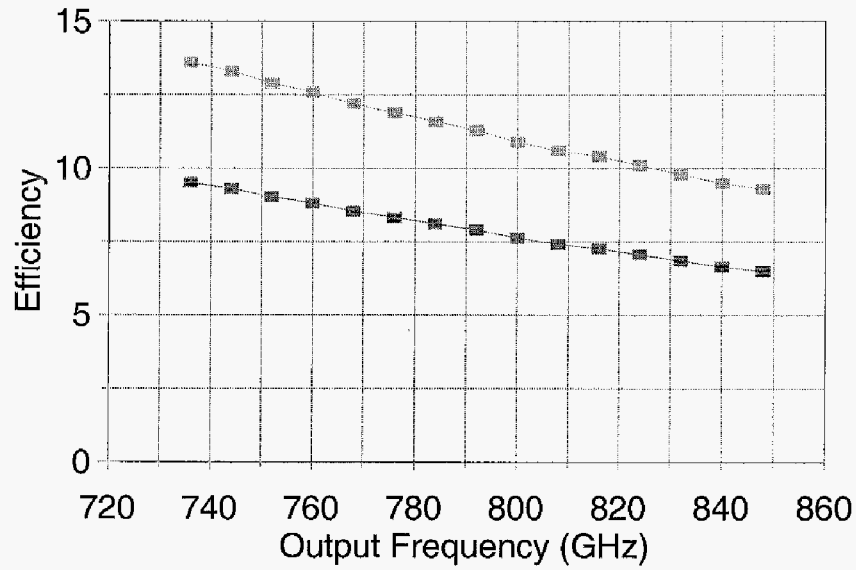


Design Considerations for Heavily-Doped Cryogenic Schottky Diode Varactor Multipliers

Calculated Effect of Tunneling Current on Efficiency



Reversed Parallel Diode Fit



Calculated Performance Compared

Design Considerations for Heavily-Doped Cryogenic Schottky Diode Varactor Multipliers

$n = n_0 + n_1$

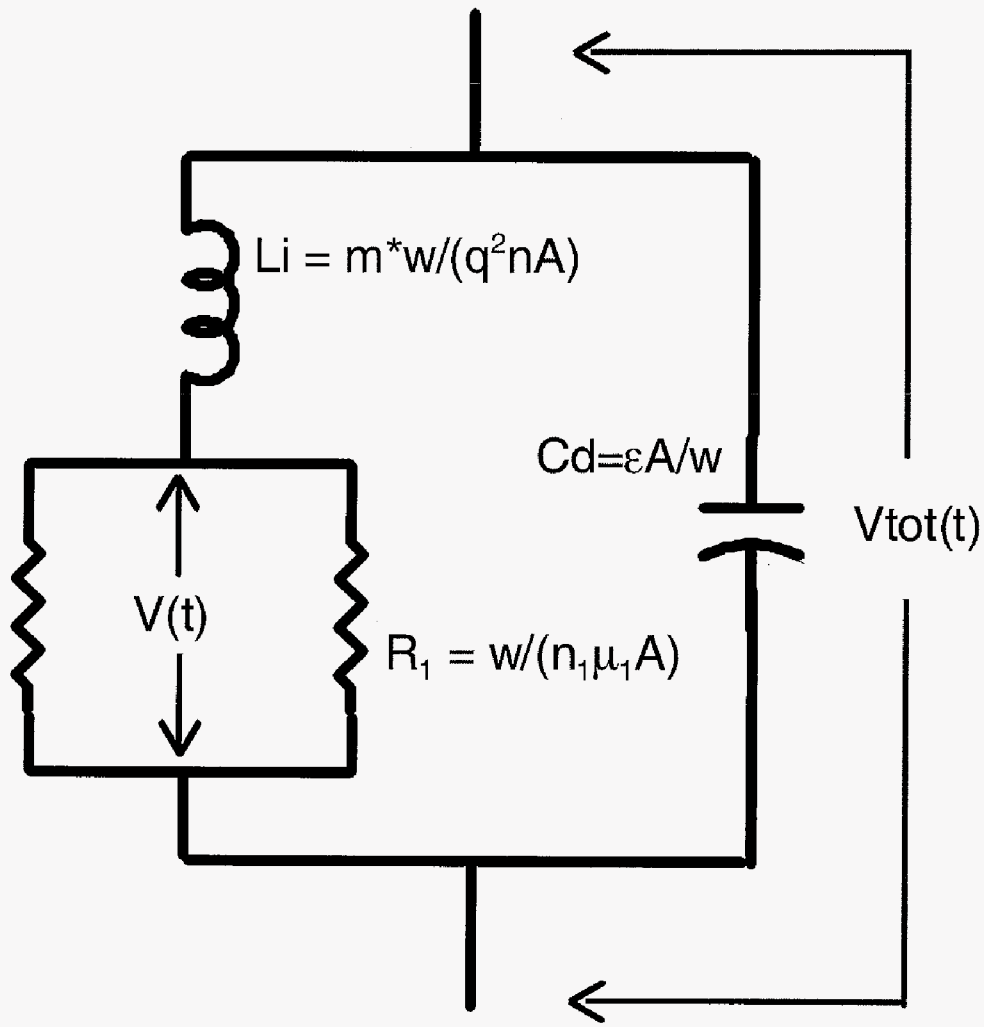
n1s(V) = static value to fit current to K-M formula

μ_0 = low field mobility
μ_1 = upper valley mobility model, ~ 400 $cm^2/V \cdot s$

$R_0 = w/(n_0 \mu_0 A)$

$$\frac{dn1}{dt} = \frac{n1s(V) - n1(t)}{\tau}$$

$$\frac{di}{dt} = \frac{Vtot(t) - V(t)}{Li}$$



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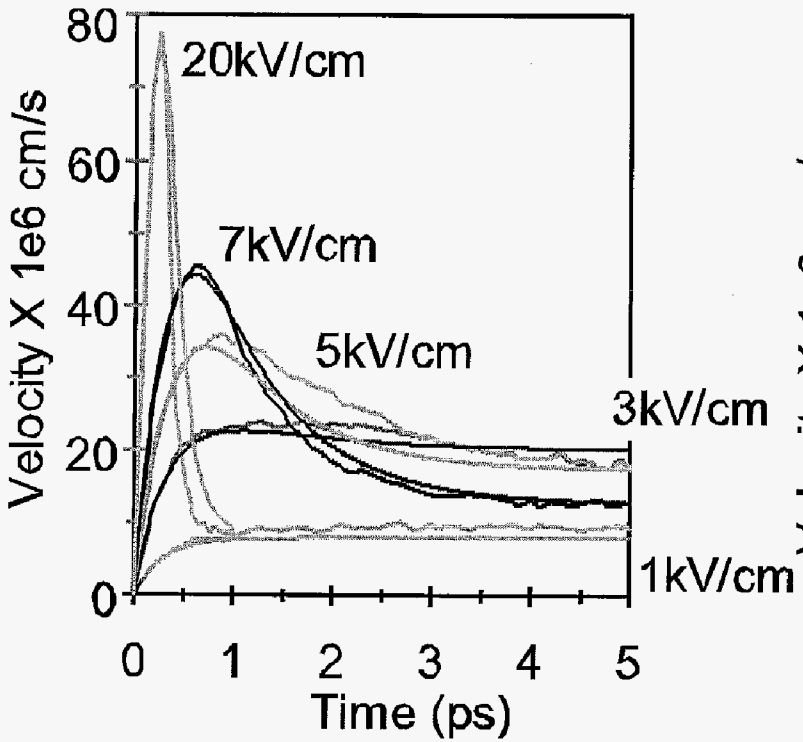
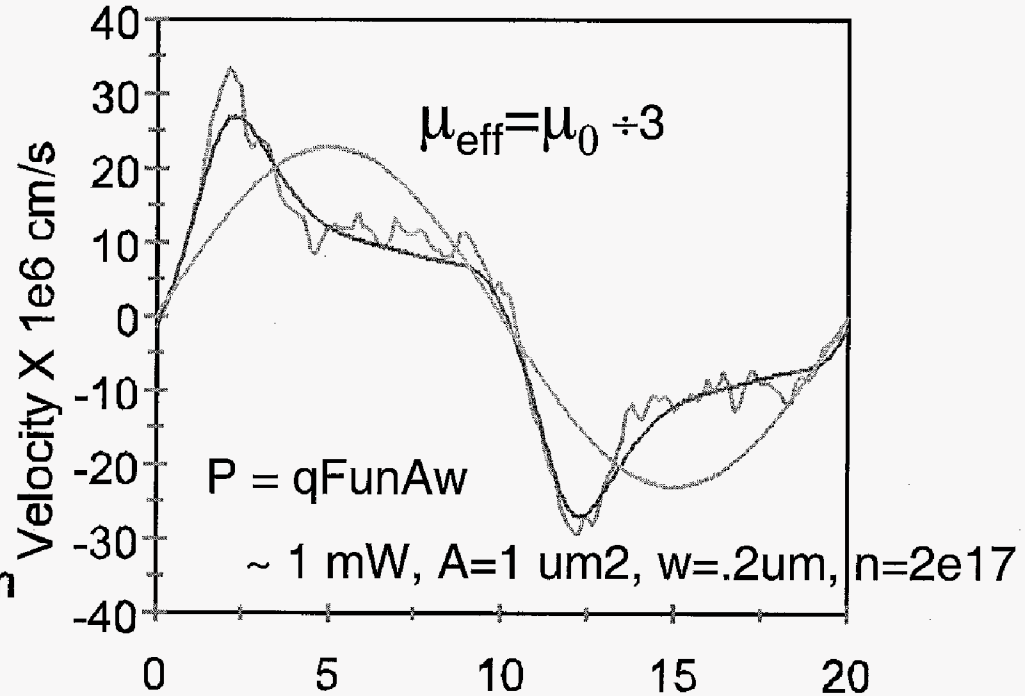


Stepped Field Comparison



Sinusoid Comparison plus effective "resistance" 3.5 times the DC resistance

Design Considerations for Heavily-Doped Cryogenic Schottky Diode Varactor Multipliers

- Improvement of saturation model using Monte Carlo or balance equation analysis.
- Insertion of saturation model into HB simulator for design.
- More and improved measurements.

Design Considerations for Heavily-Doped Cryogenic Schottky Diode Varactor Multipliers

- Tunneling current effects the efficiency, can't be eliminated but can be modeled.
- A simple model of current saturation useful for rapid HB simulation was described.
- Even the simple model will require some effort to invorporate into HB calculations.