Plasmonic Noise of Field-Effect Transistors Operating at Terahertz Frequencies

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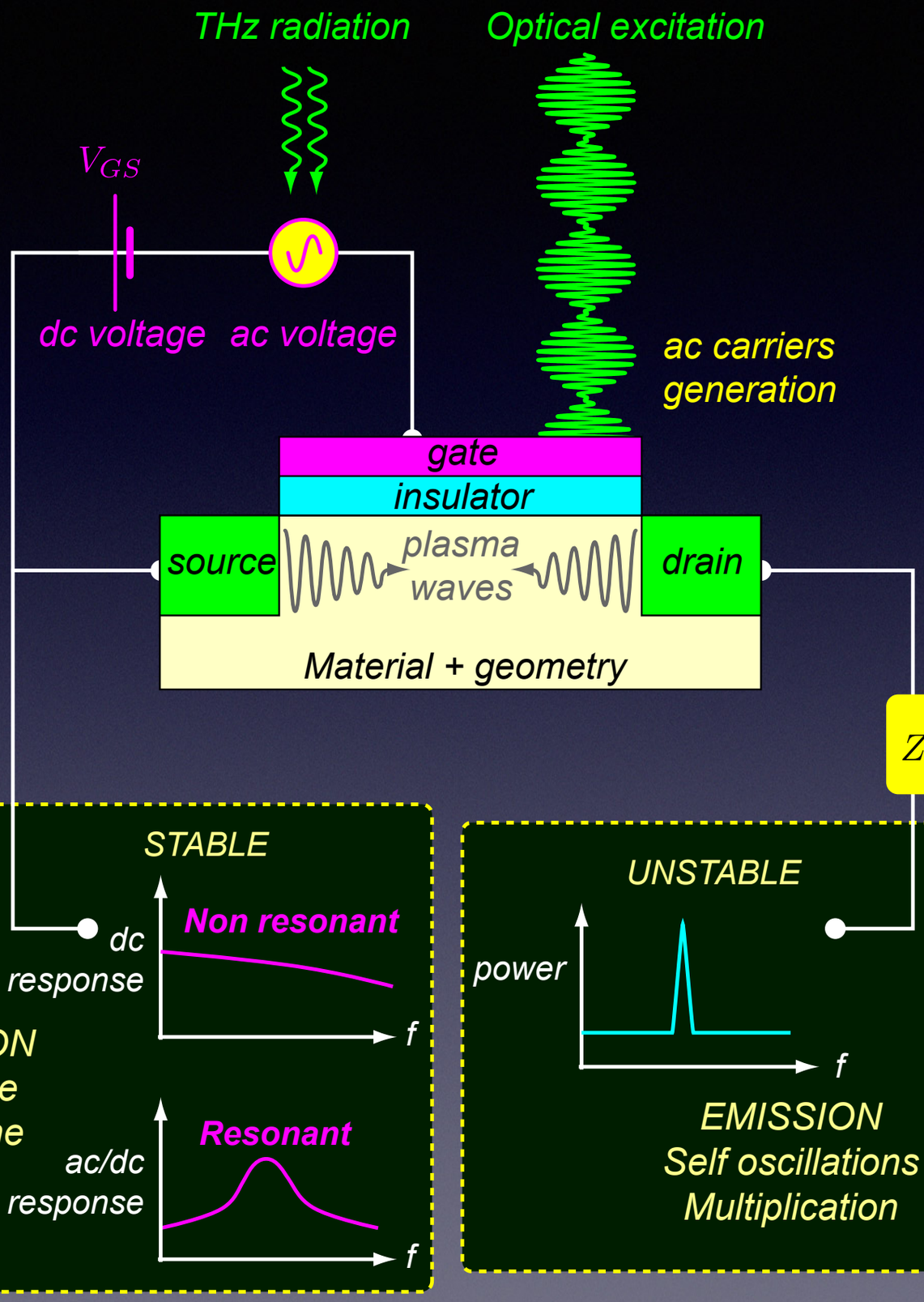
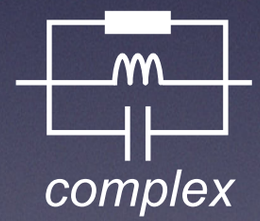
Physical Scenario

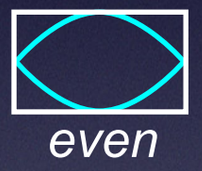
INPUT

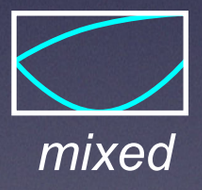


BOUNDARY



MODES





OUTPUT

1st ingredient: Transport

Continuity $$\frac{\partial n}{\partial t} + \frac{\partial nv}{\partial x} = 0$$

Hydrodynamic $$\frac{\partial v}{\partial t} + \frac{\partial}{\partial x}\left[\frac{v^2}{2} + \frac{e}{m^*}\varphi\right] + e\nu D\frac{\partial n}{\partial x} + v\nu = \tilde{f}$$

Material parameters			
Effective mass m^*	Relaxation rate ν	Diffusion D	Langevin force $\tilde{f}$

2nd ingredient: Potential

Pseudo 2D Poisson

$$\underbrace{\varepsilon_c \frac{\partial^2 \varphi}{\partial x^2}}_{\text{longitudinal}} + \underbrace{\varepsilon_s \frac{U_g - \varphi}{d(x)\delta}}_{\text{transverse}} = \frac{e}{\varepsilon_0}\left[n(x) - N_D(x)\right]$$

δ

Geometrical parameters			
Channel thickness δ	Gate distance $d(x)$	3D $d\delta \to \infty$	2D $d\delta \to 0$

3rd ingredient: Boundaries

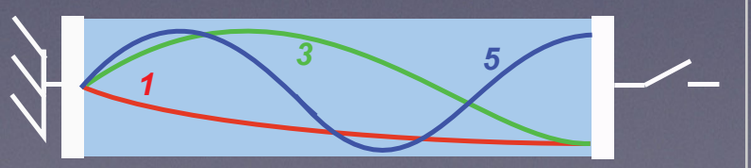
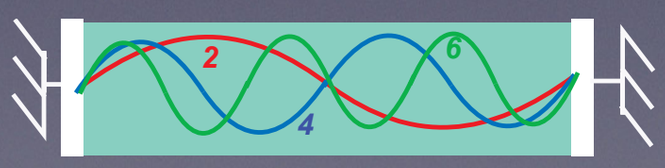
Voltage driven

$$\begin{cases} \varphi(0) = 0 \\ \varphi(L) = V_D \end{cases}$$

Current driven

$$\begin{cases} \varphi(0) = 0 \\ \frac{\partial E(L,t)}{\partial t} = \frac{1}{\varepsilon_c \varepsilon_0} \left[j_{tot} - en(L,t)v(L,t) \right] \end{cases}$$

External circuit

Open circuit	Closed Circuit	Complex charge
		$\overline{Z} = R + jX$

4th ingredient: Noise

$$S_{\xi\xi}(\omega) = \int_0^L n(x_0)|G_\xi(\omega, x_0)|^2 S_{ff}(x_0)dx_0$$

$\xi = \begin{cases} U \text{ Voltage} \\ J \text{ Current} \end{cases}$

Spectral response function

$\frac{4k_BT\nu}{m^*}$ Noise source

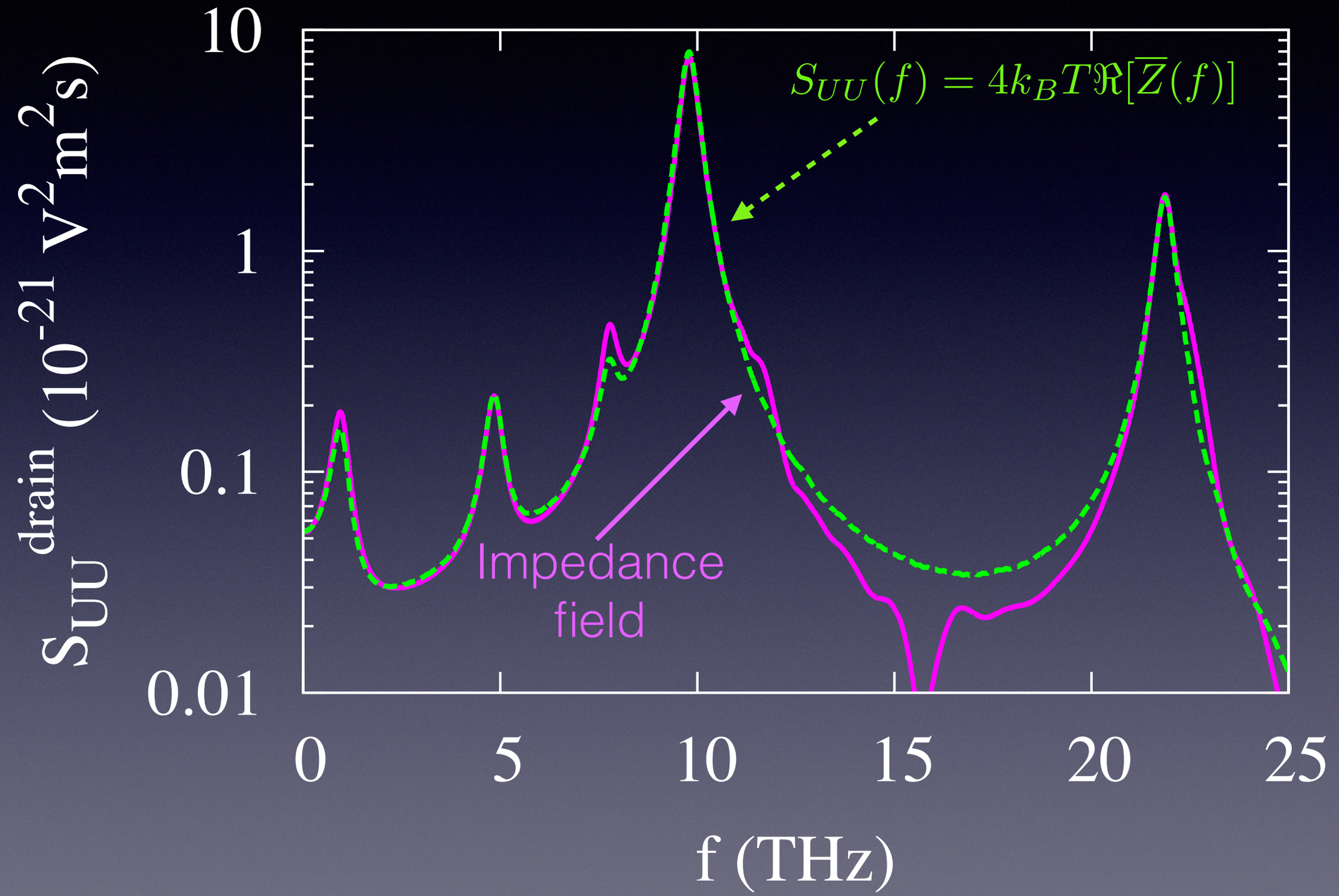
Transfer Impedance Field		
Voltage and Current	Local contribution	Admittance,Impedance
S_{UU}, S_{JJ}	$\delta S_{\xi\xi}$	$\overline{Y}, \overline{Z}$

Overview of

- *open problems,*
- *critical points,*
- *difficulties,*
- *etc…*

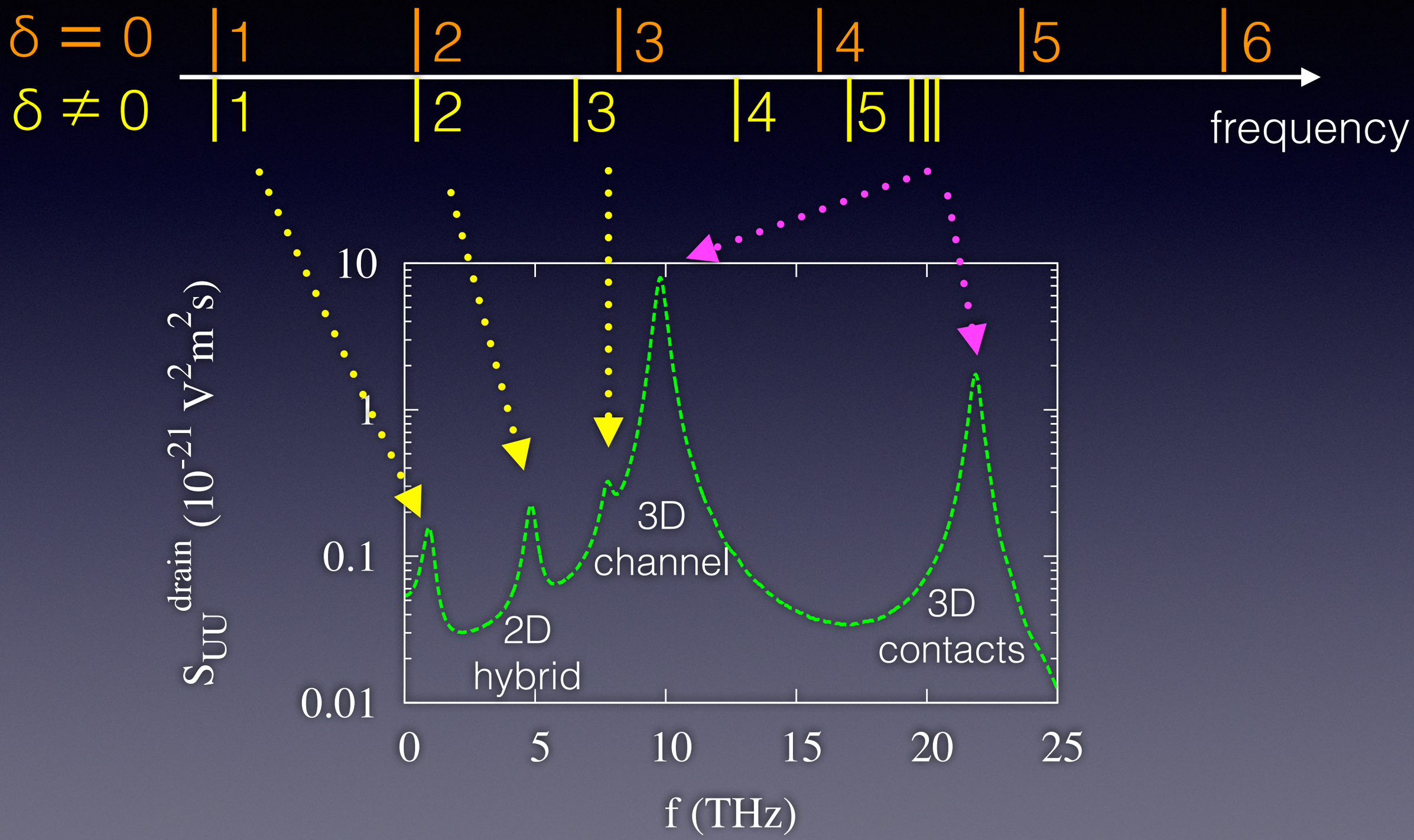
PROBLEM 1: NOISE CALCULATION

Can we apply Nyquist relation to transistors?



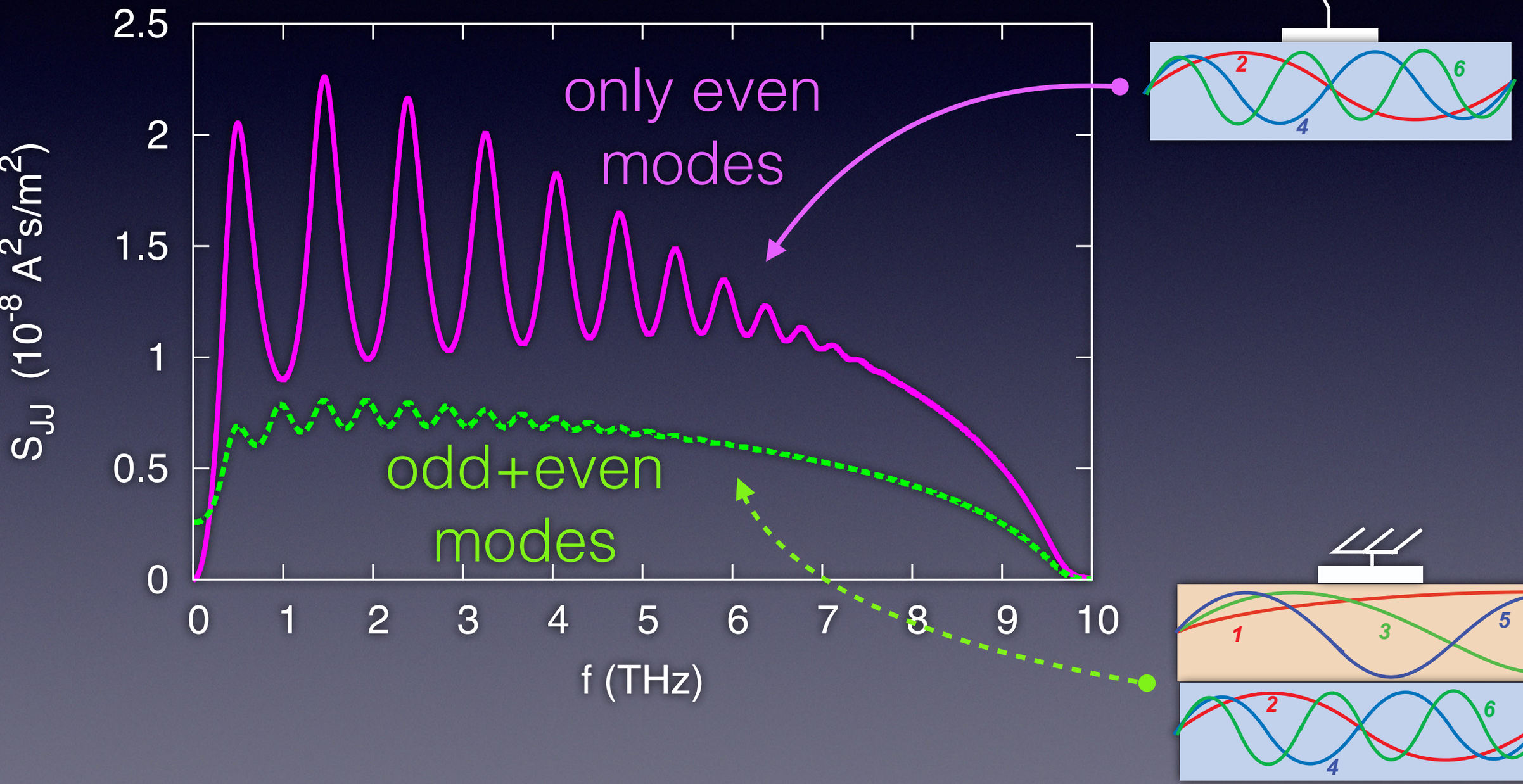
PROBLEM 2: DIMENSIONALITY

What is the role of the channel thickness δ?



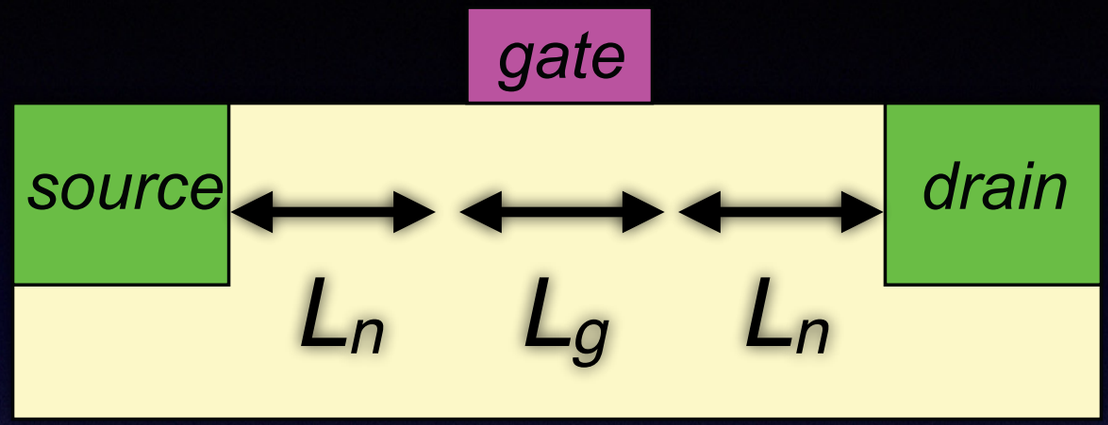
PROBLEM 3: ENVIRONMENT

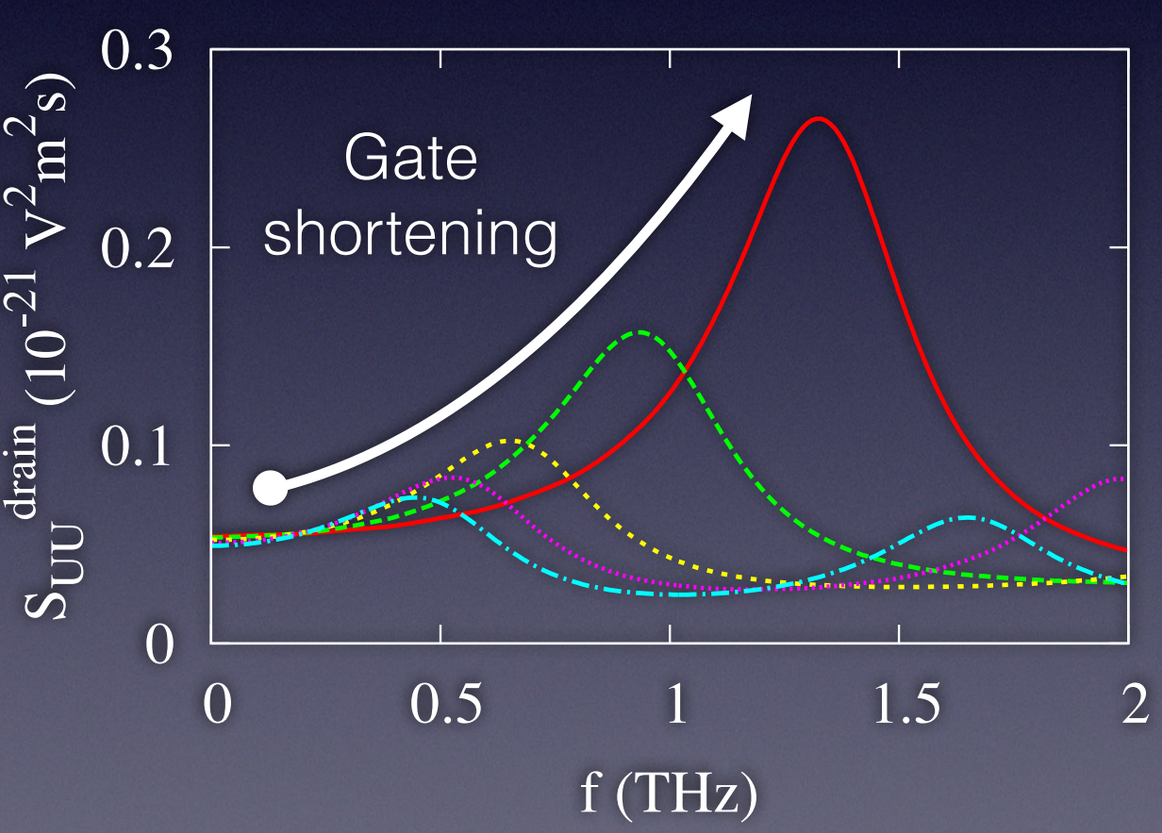
Can we tune noise by the embedding circuit?

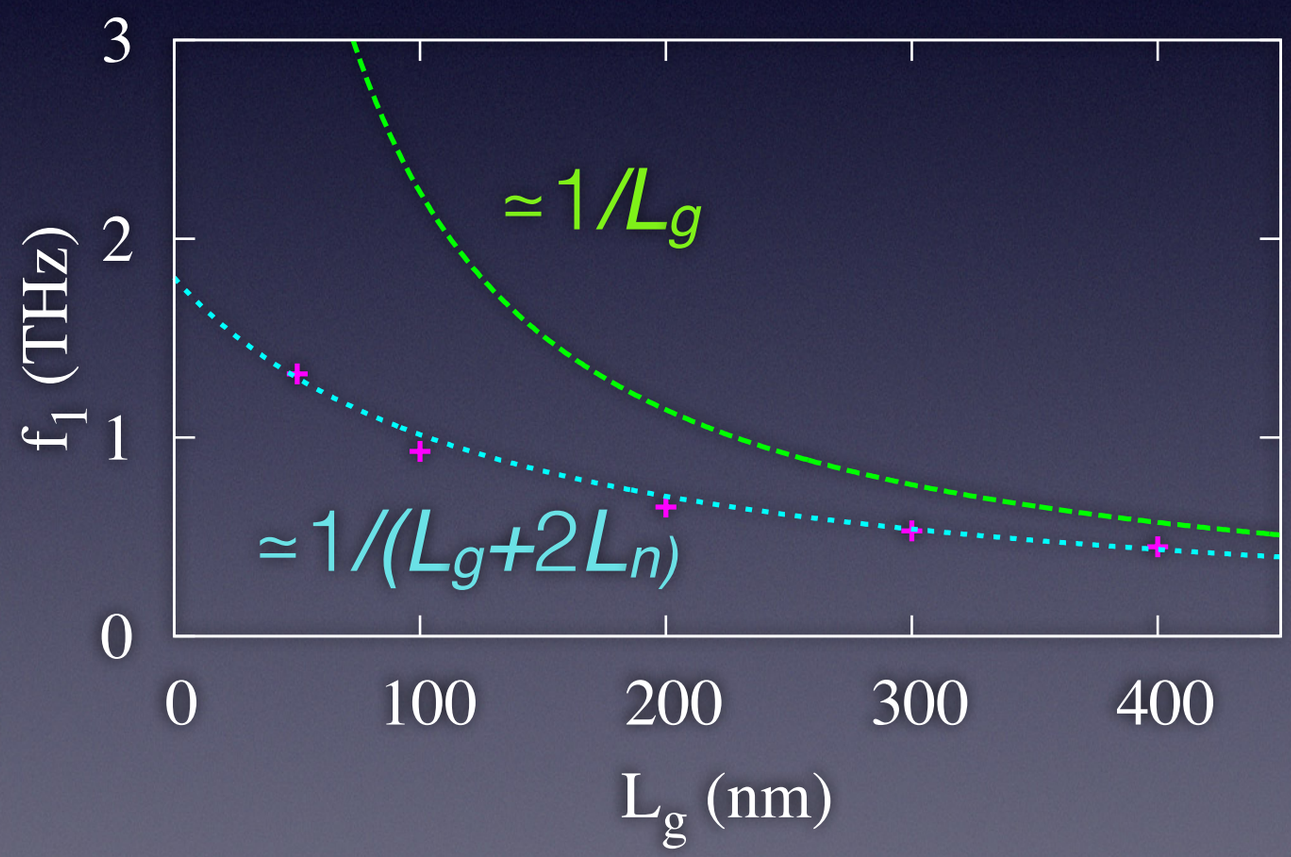


PROBLEM 4: DEVICE TOPOLOGY

What is the effect of gate/channel lengths?

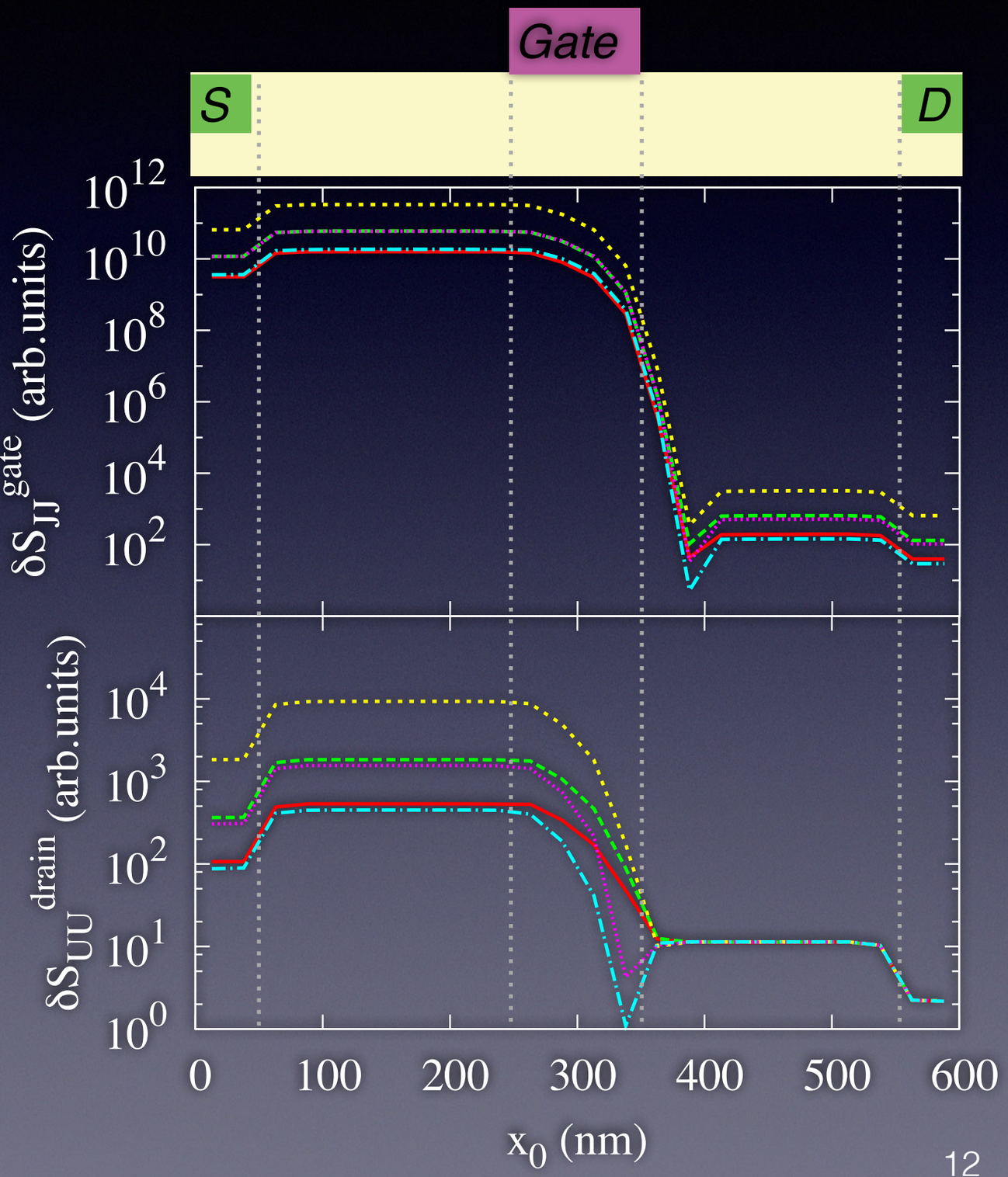






PROBLEM 5: NOISE DISTRIBUTION

Where the noise comes from?



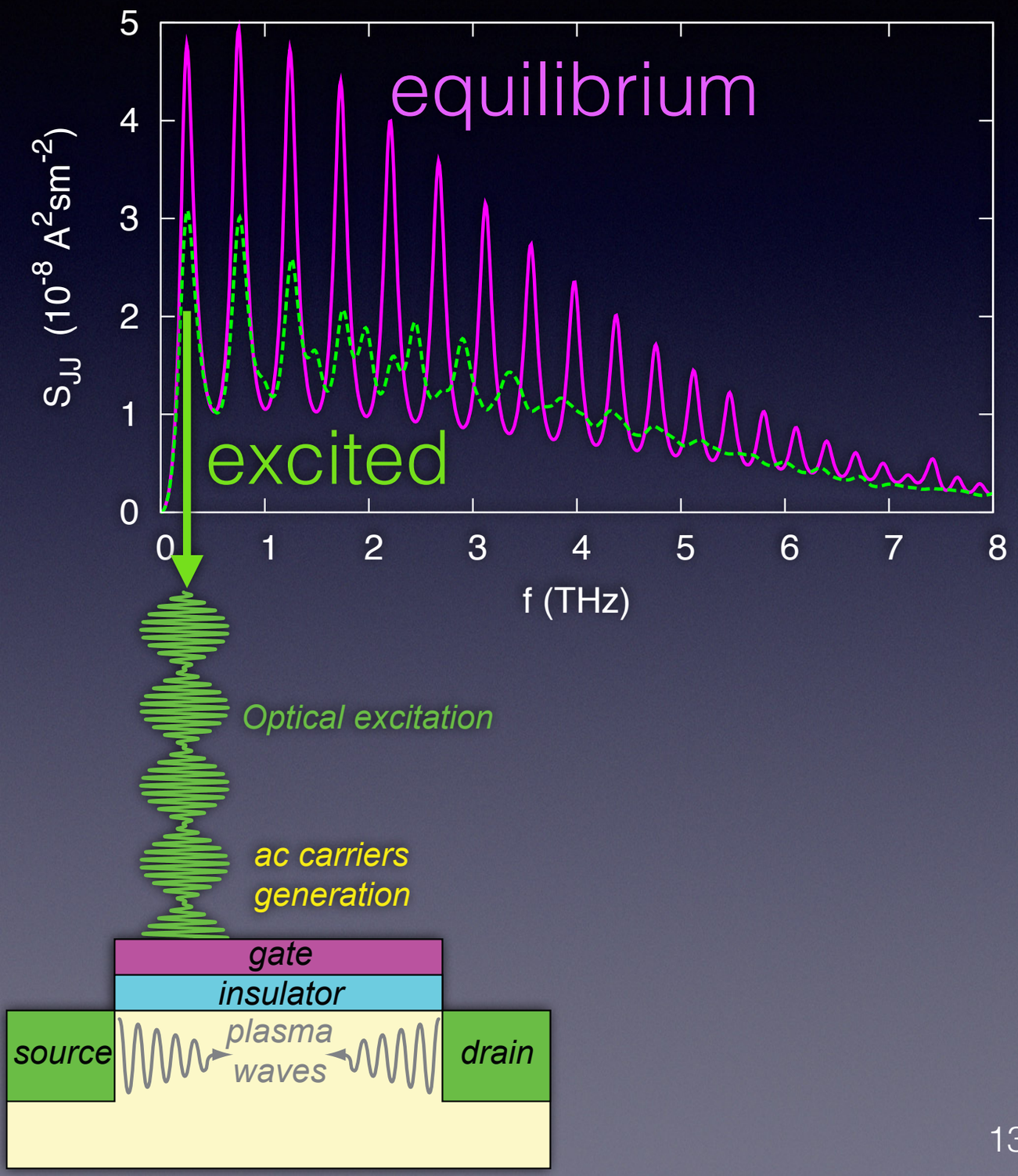
Local contribution

$$\delta S_{\xi\xi} = n(x_0)|G_\xi(\omega, x_0)|^2 S_{ff}(x_0)$$

$$S_{\xi\xi}(\omega) = \int_0^L \delta S_{\xi\xi} dx_0$$

PROBLEM 6: NOISE SUPPRESSION

What is the effect of an external excitation?



Thermally excited

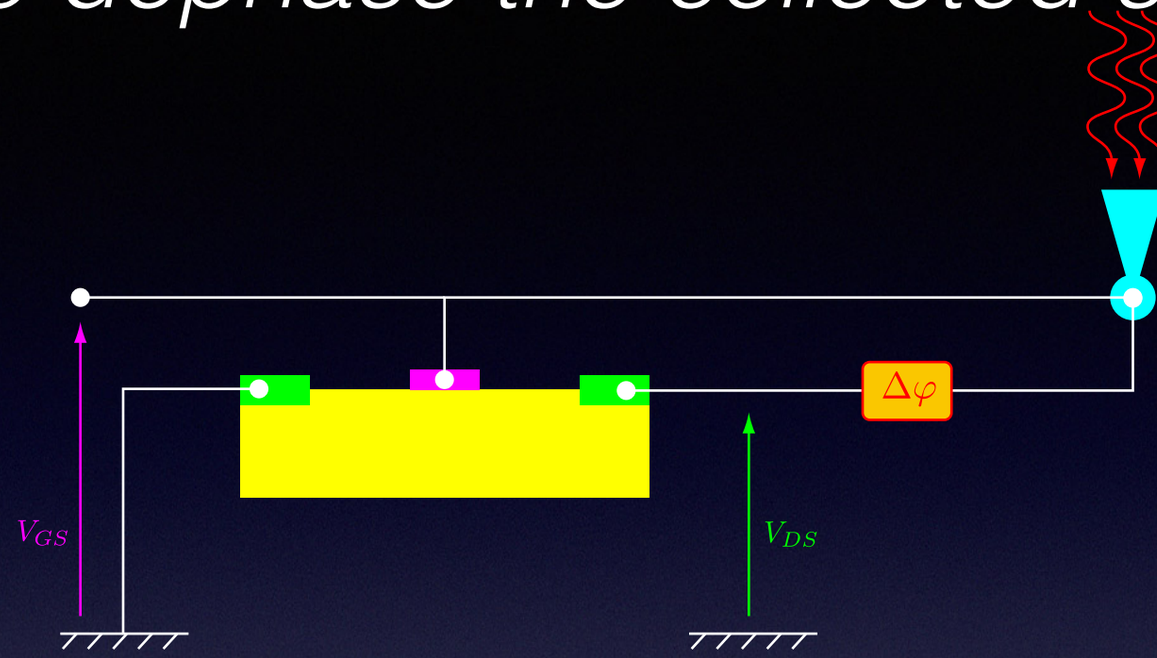
vs

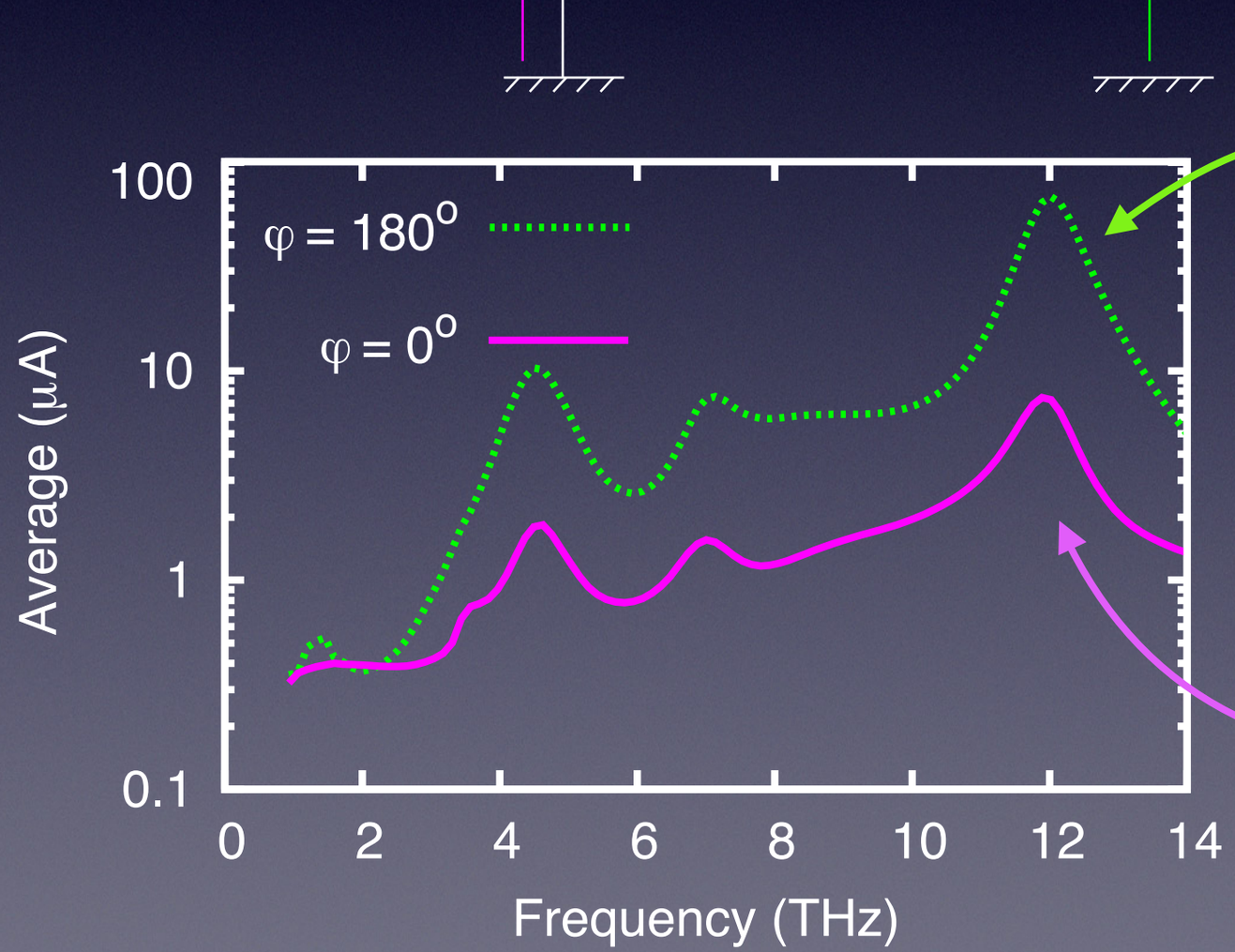
optically excited

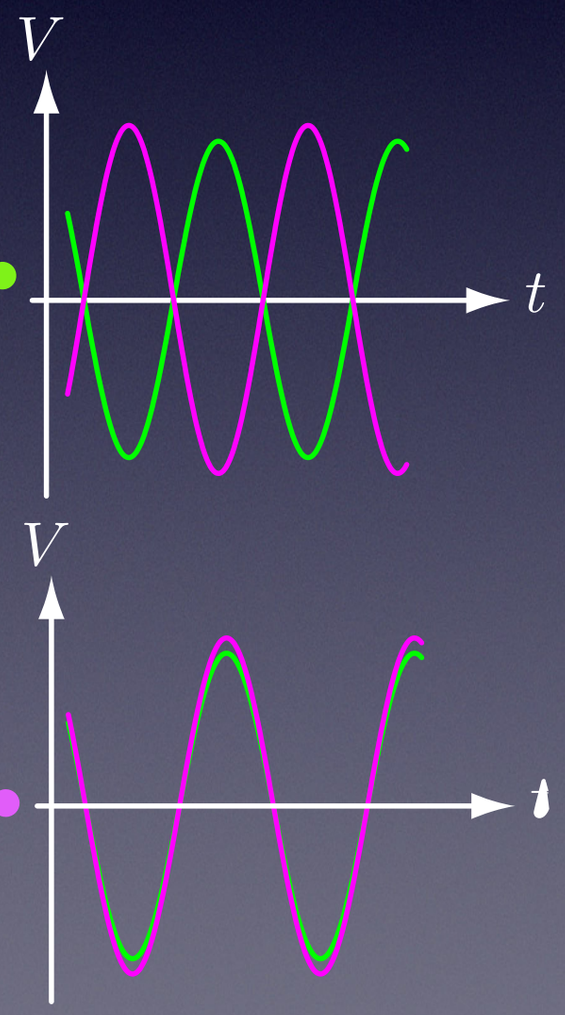
plasmonic noise

PROBLEM 7: IMPROVE SIGNAL-TO-NOISE

How to dephase the collected signals?

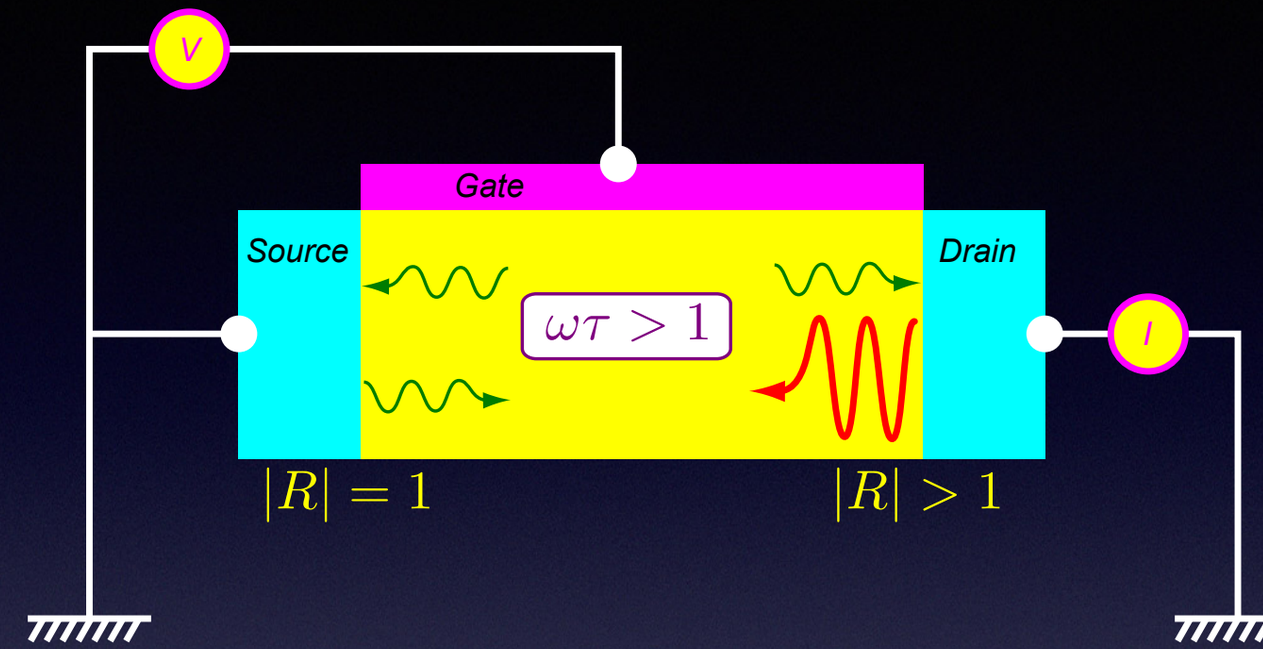


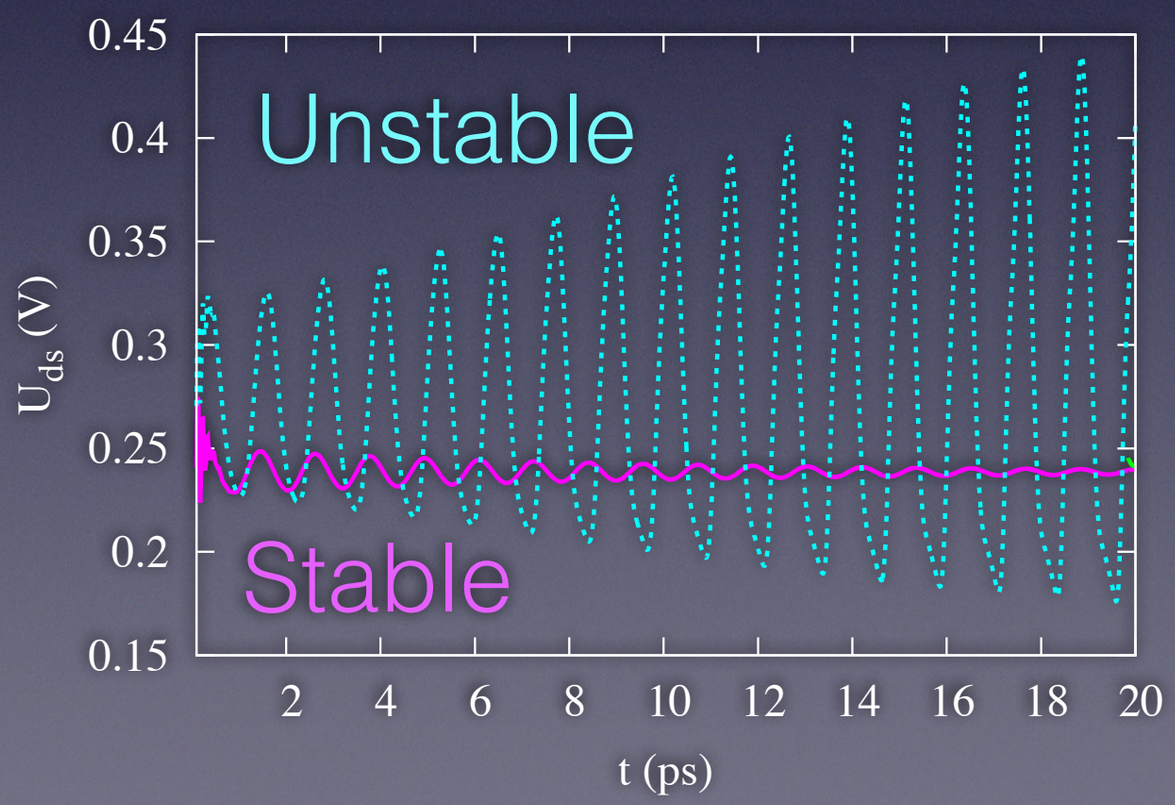


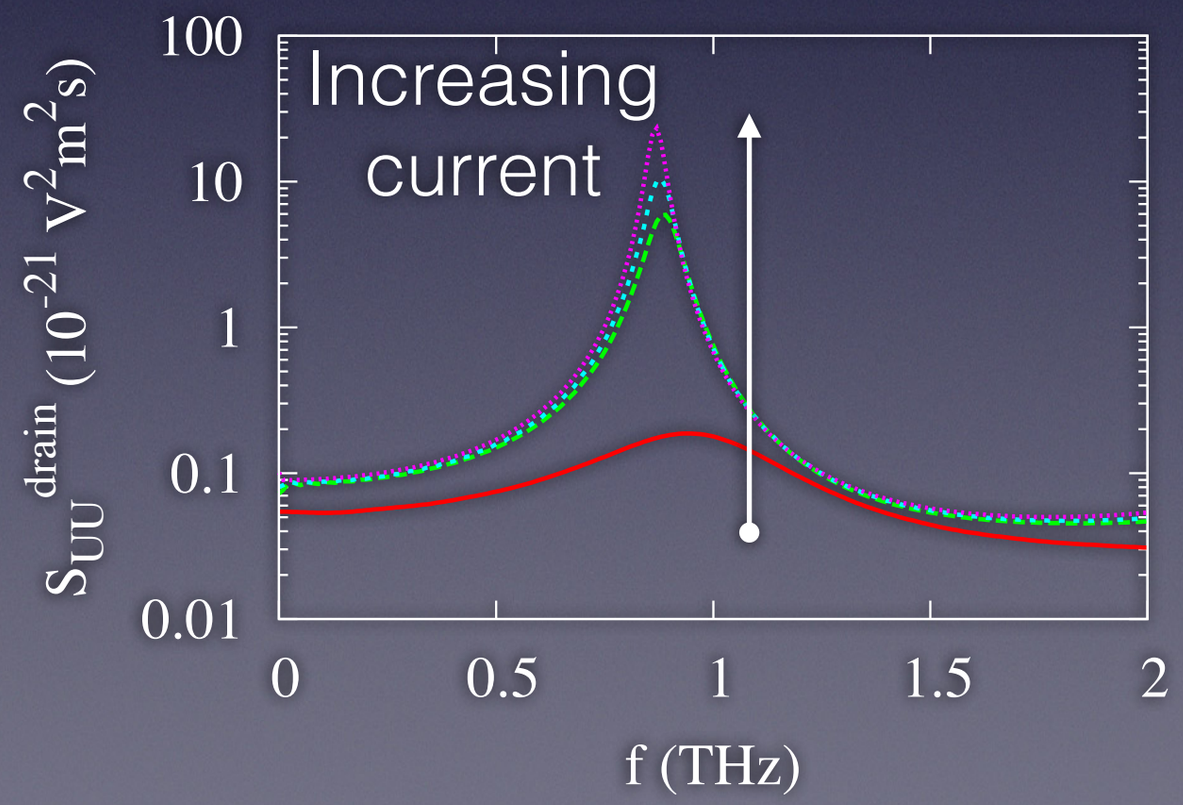


PROBLEM 8: PLASMA INSTABILITY

How to reach self-oscillations conditions?







Thank you for your ~~attention~~ answers