

8th Annual E³S Retreat, 2017

Theme 1

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Theme 1 Leader

Center for Energy Efficient Electronics Science



A Science & Technology Center

Berkeley
UNIVERSITY OF CALIFORNIA

**Massachusetts
Institute of
Technology**

STANFORD
UNIVERSITY

THE UNIVERSITY OF
TEXAS AT EL PASO

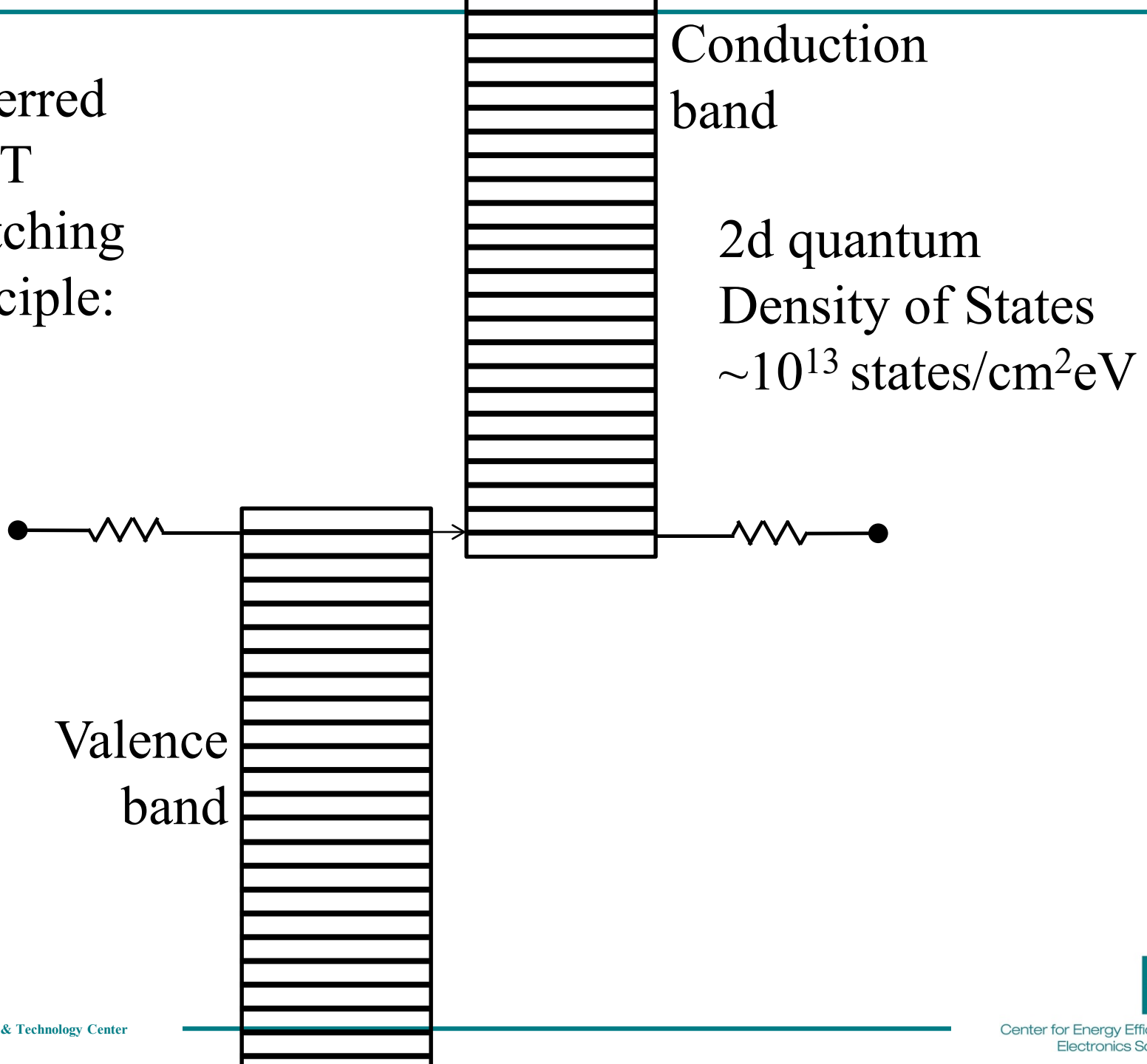
FLORIDA
INTERNATIONAL
UNIVERSITY

CALIFORNIA COMMUNITY COLLEGES
CHANCELLOR'S OFFICE



Center for Energy Efficient
Electronics Science

Preferred
TFET
Switching
Principle:



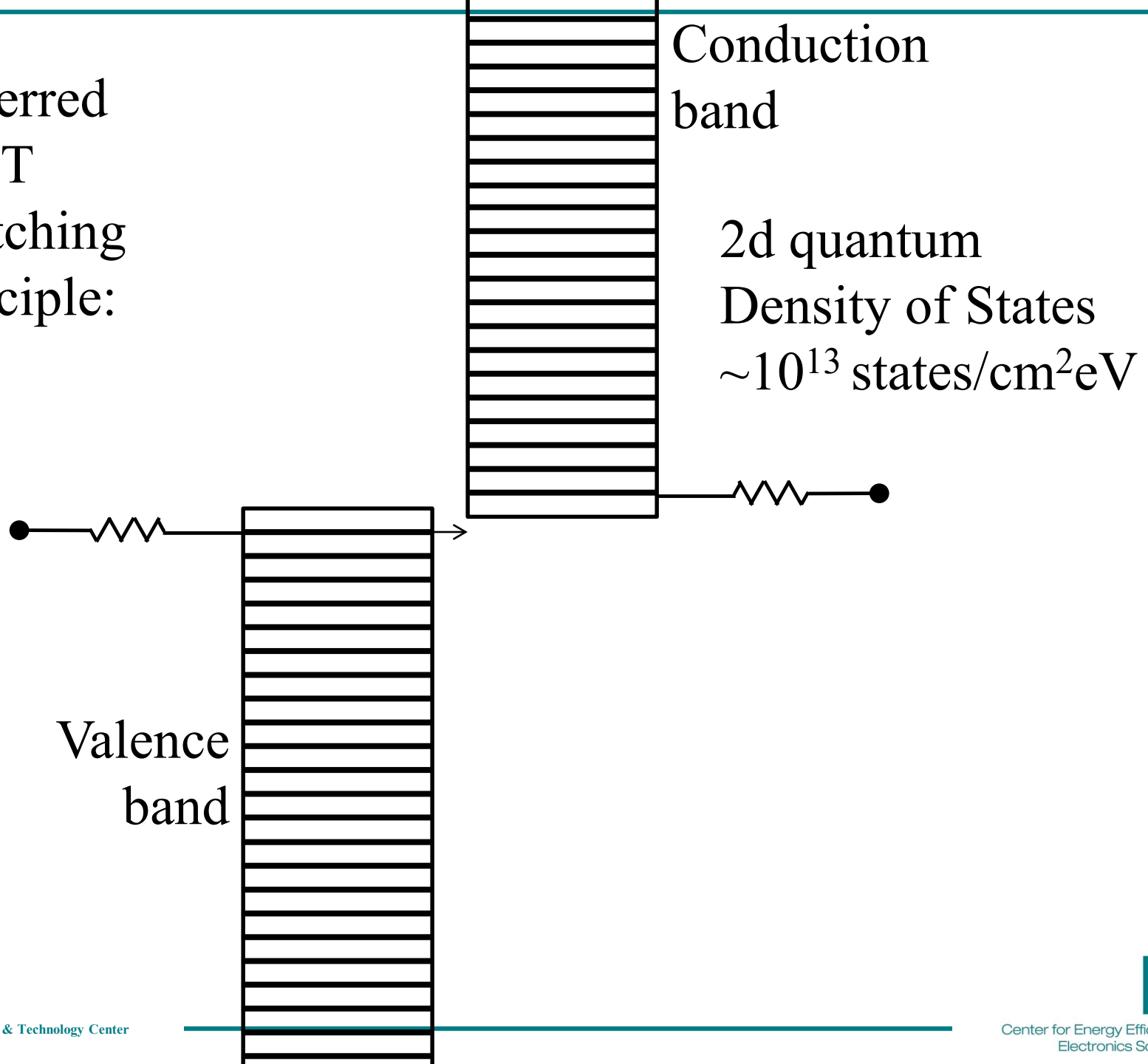
Conduction
band

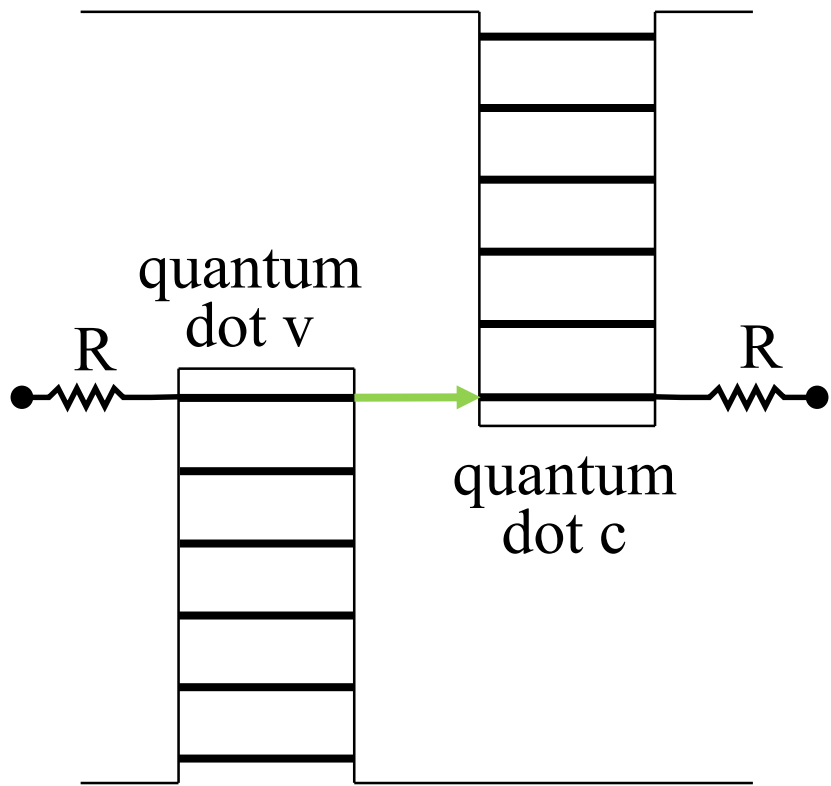
2d quantum
Density of States
 $\sim 10^{13}$ states/cm²eV

Valence
band

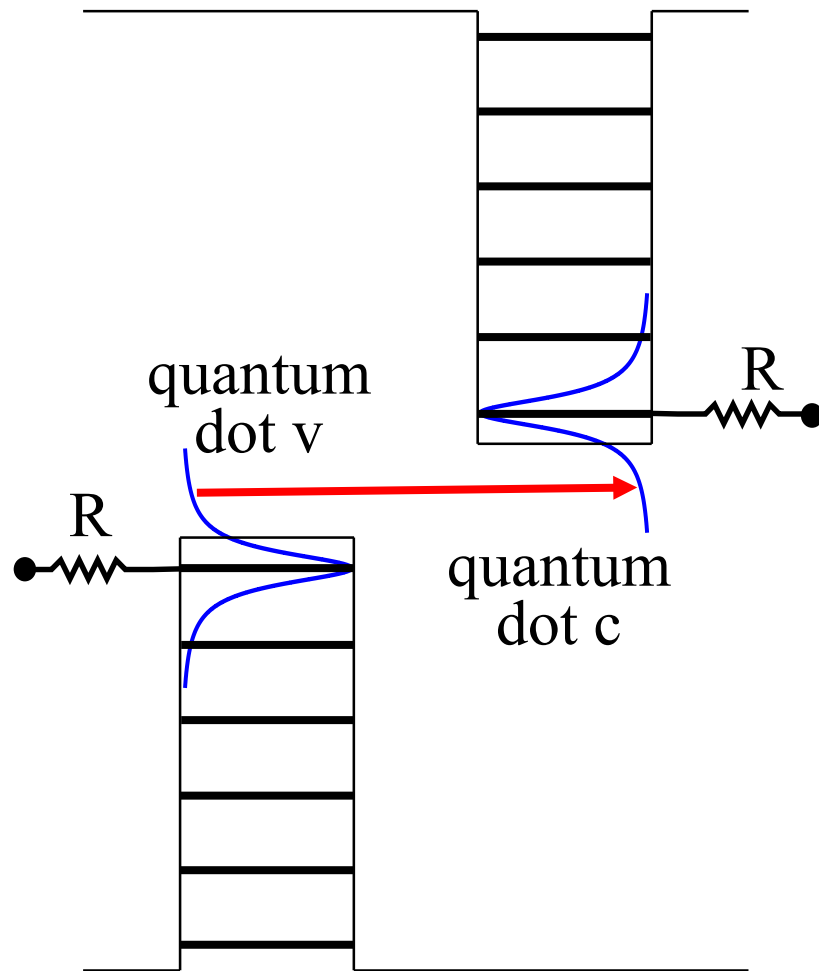


Preferred
TFET
Switching
Principle:





(a) aligned



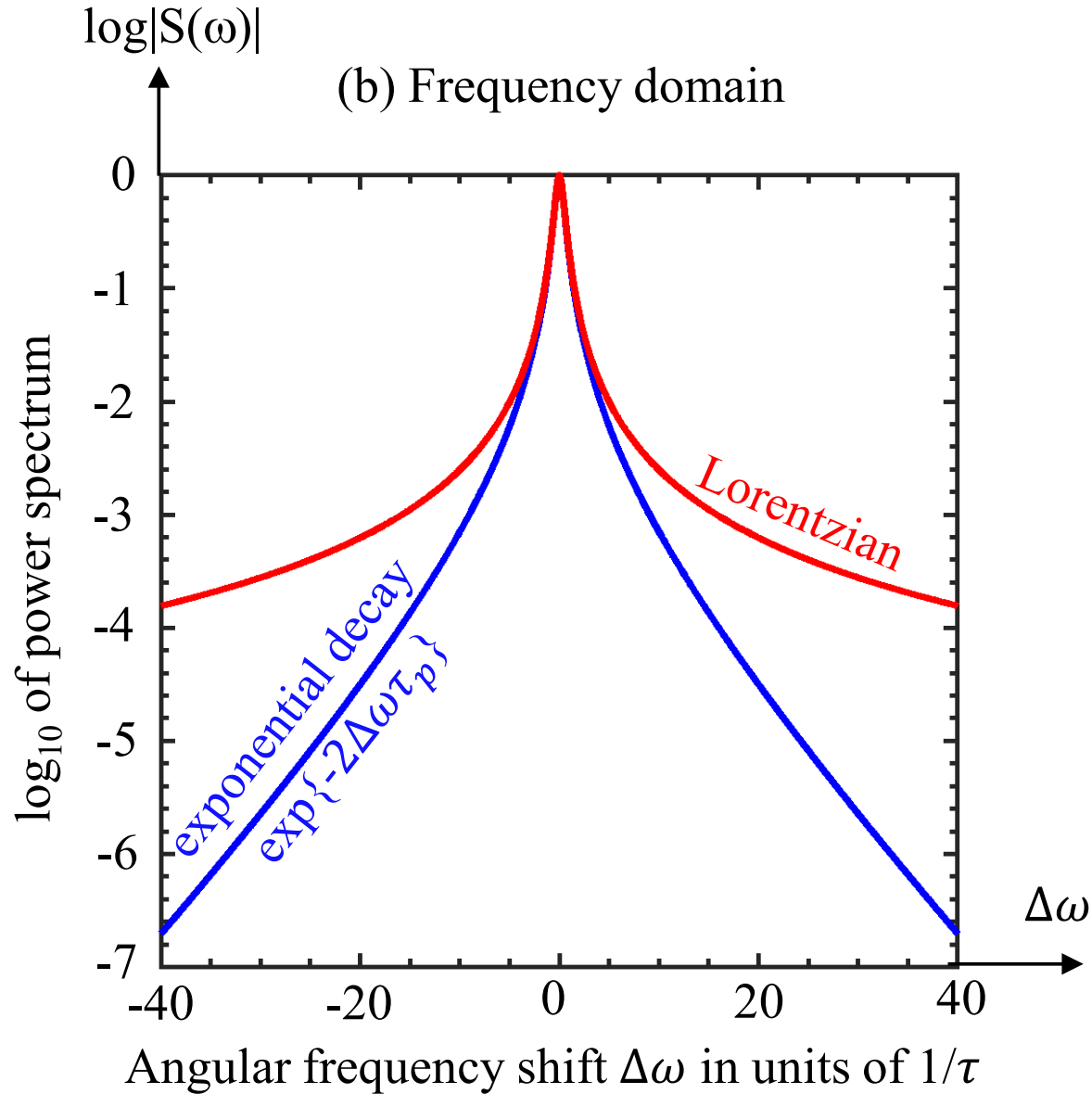
(b) misaligned

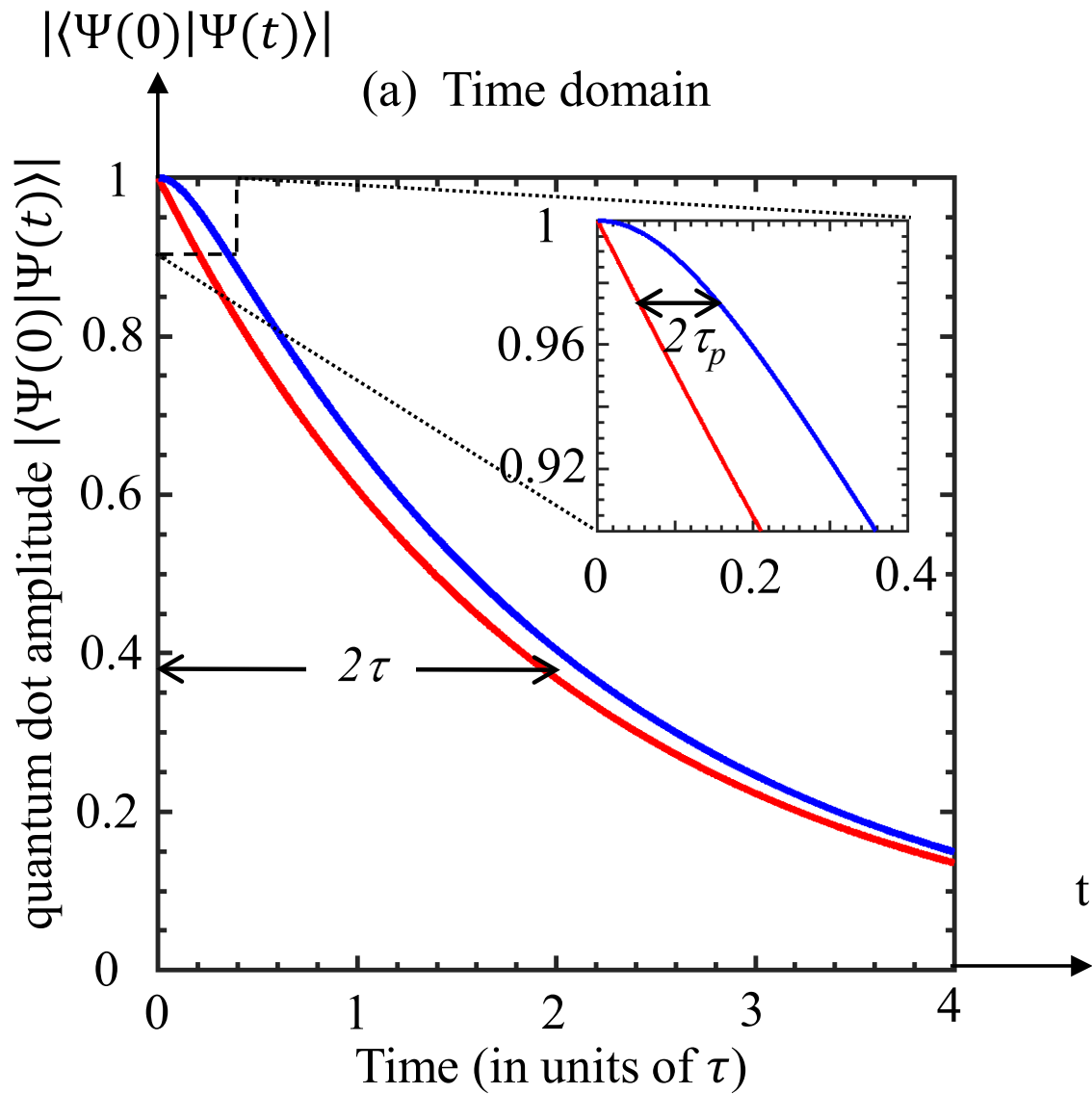
What happens to a sharp quantum level when it interacts with a contact?

It might decay exponentially by Fermi's Golden Rule: $\exp\{-t/\tau\}$
where τ is the lifetime of an electron in the quantum state
before it decays into the wire.

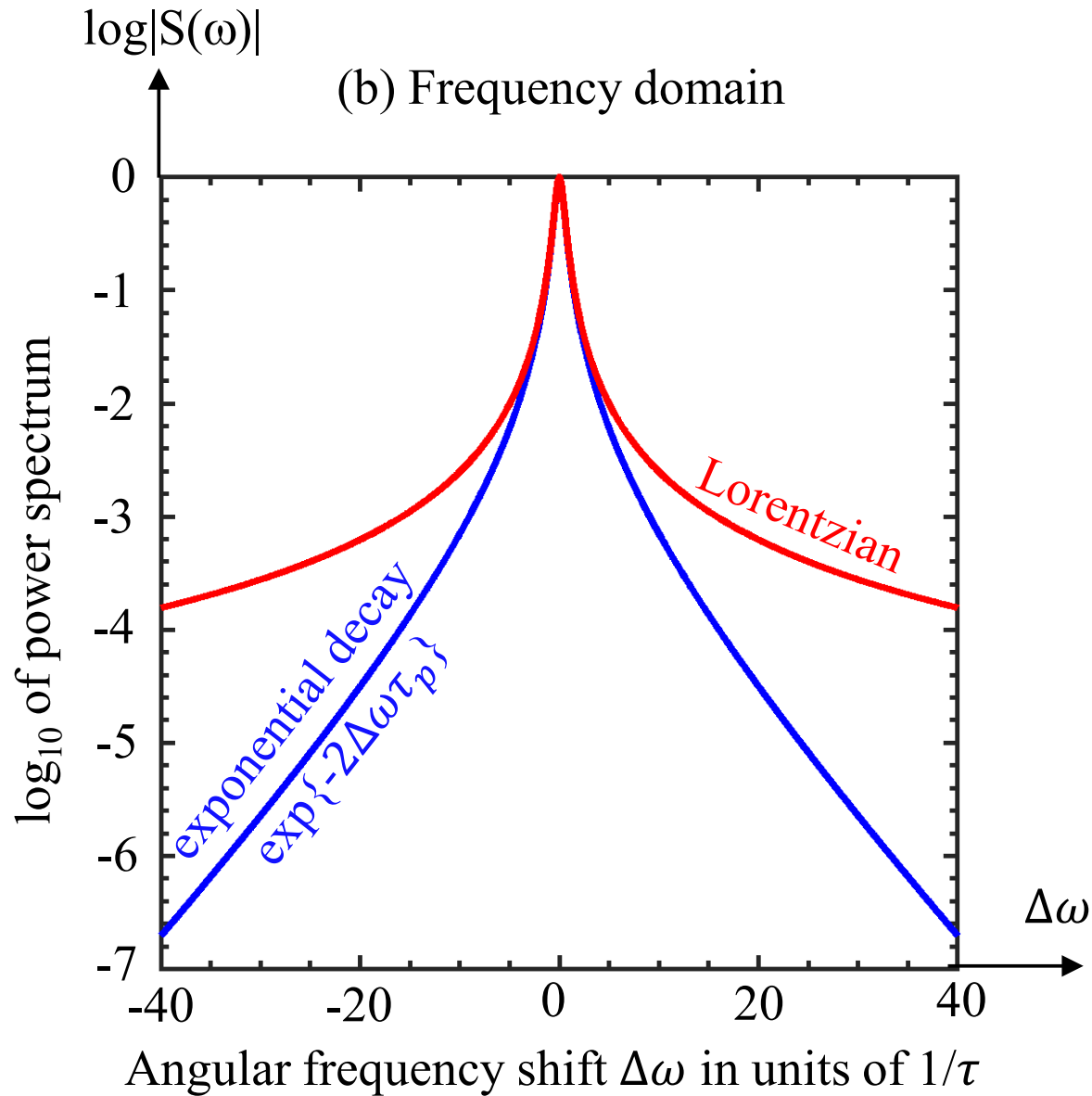
The Fourier Transform of $\exp\{-t/\tau\}$ is the Lorentzian: $\frac{1}{\Delta\omega^2 + \left(\frac{1}{\tau}\right)^2}$

The tFET concept would fail if spectral lineshapes were Lorentzian:

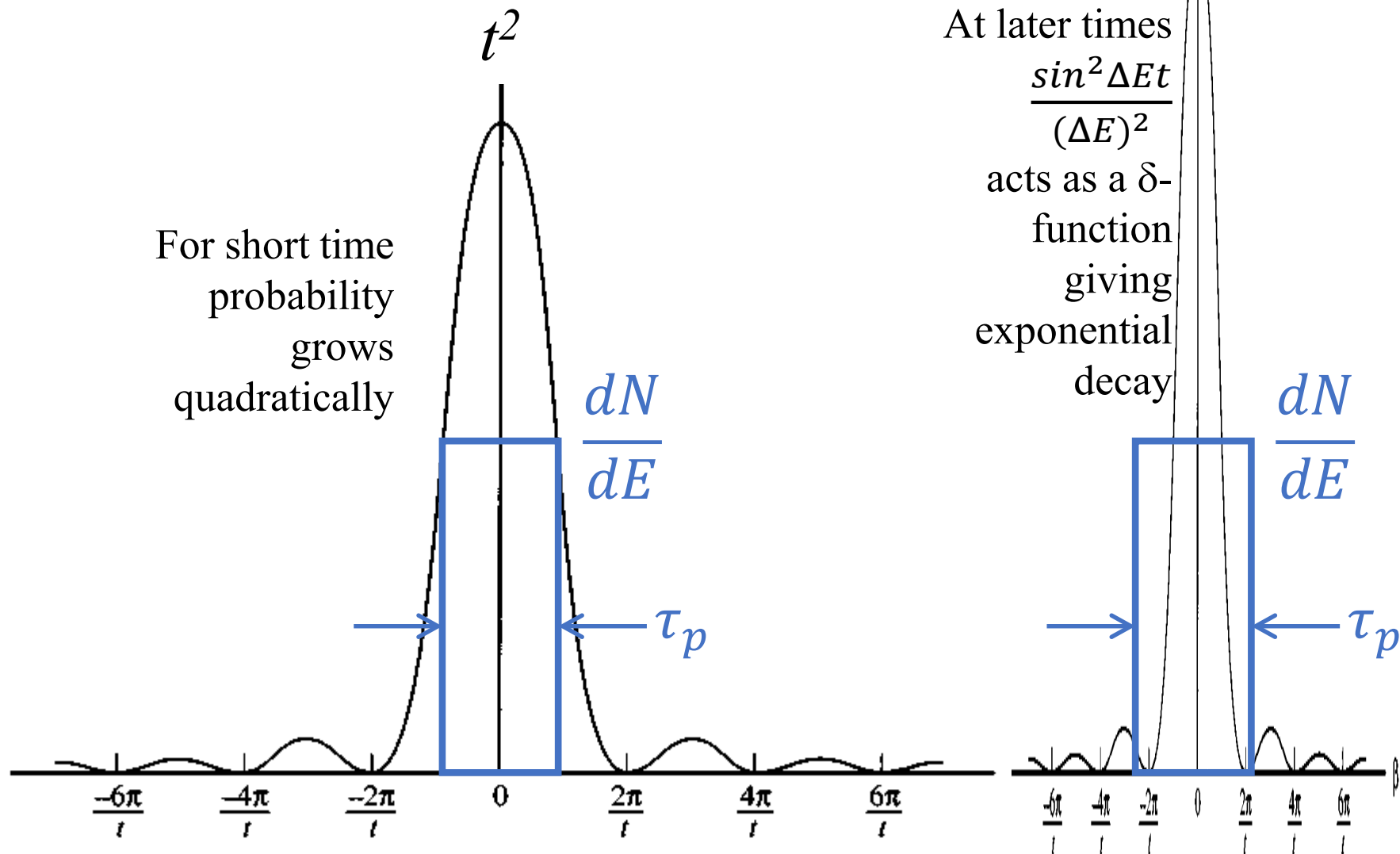


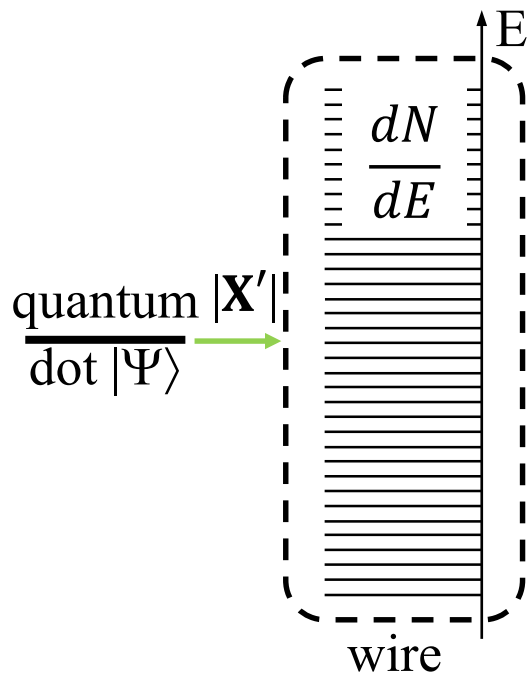


The initial parabolic decay rescues the tFET concept:



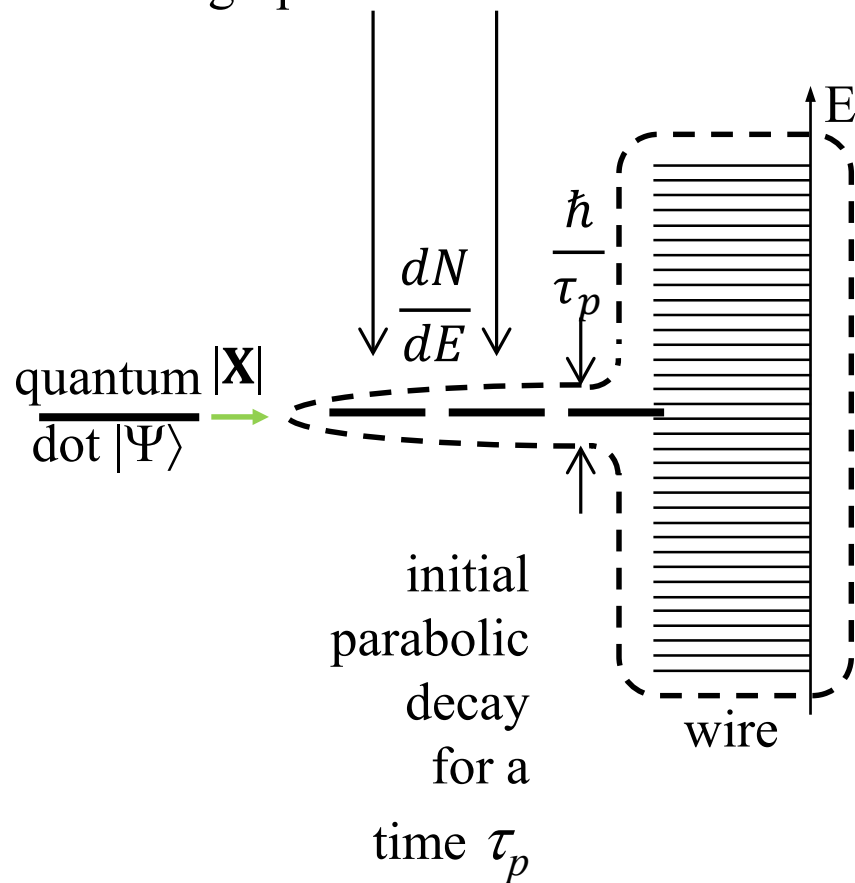
Fermi's Golden Rule:
$$\int \left(\frac{\sin^2 \Delta E t}{(\Delta E)^2} \times \frac{dN}{dE} \right) dE$$





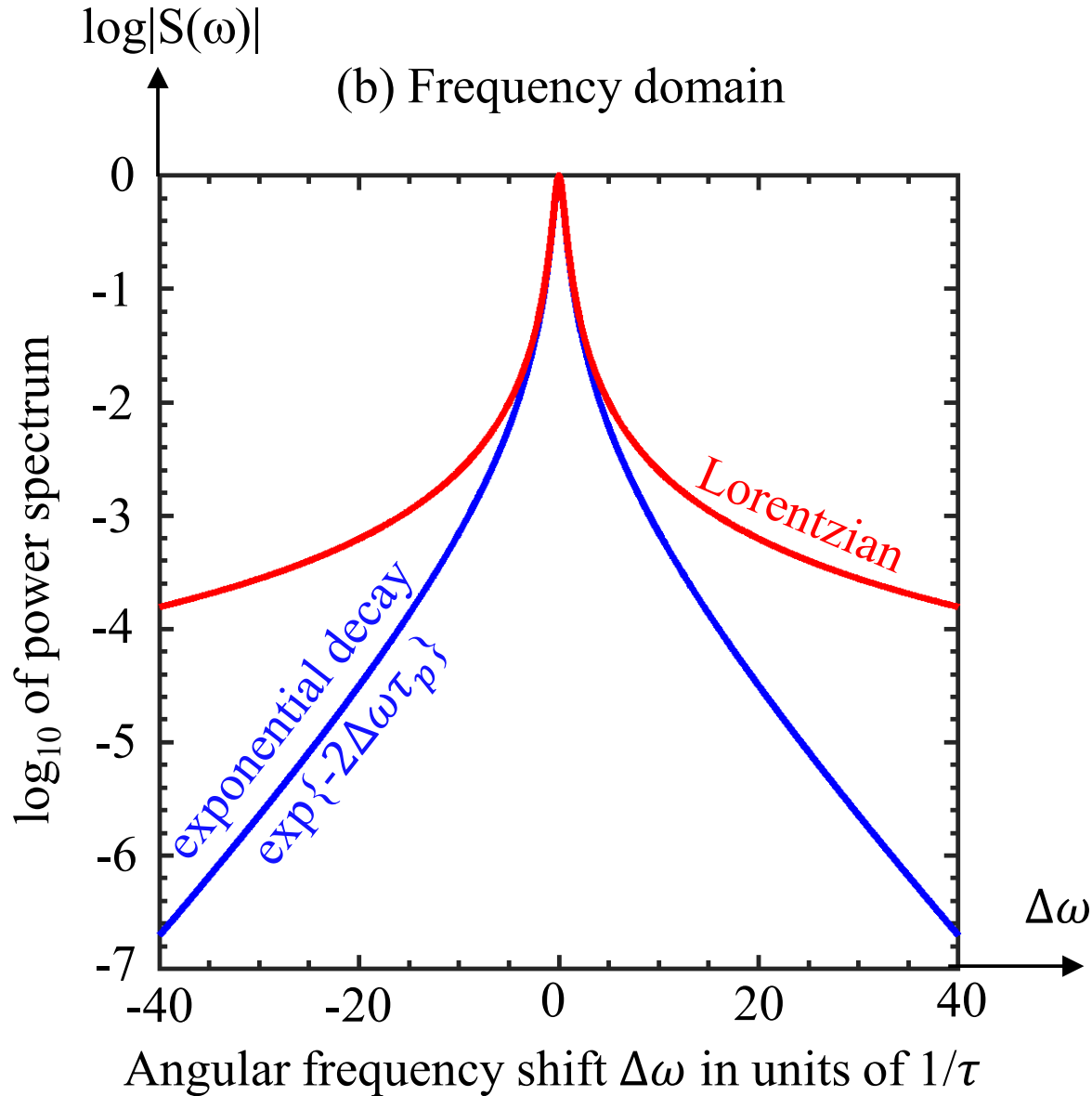
Lorentzian
straight
Fermi's
Golden
Rule

This needs to be a
narrow-band metallic
graphene nano-ribbon



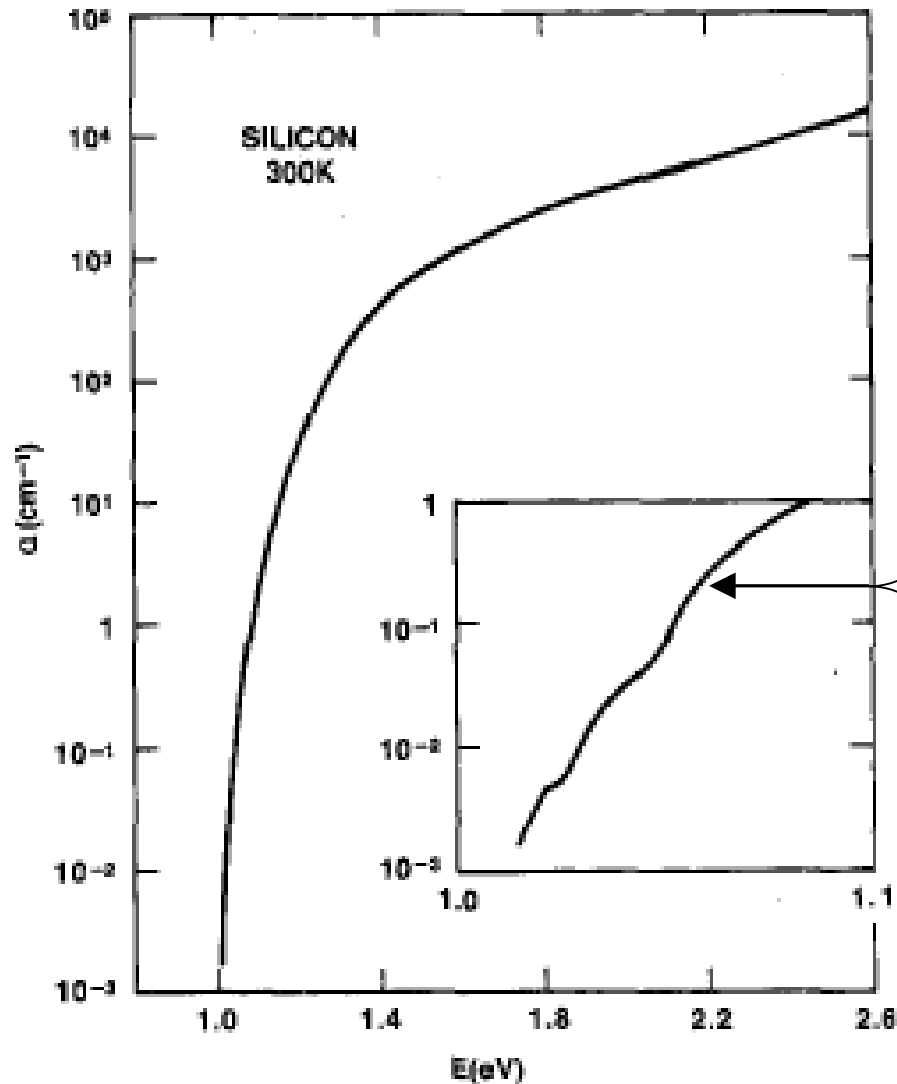
initial
parabolic
decay
for a
time τ_p

The initial parabolic decay rescues the tFET concept:



This mechanism
also provides a
Universal
explanation for
Urbach tails

The optical absorption coefficient, $\alpha(h\nu)$, of Si at 300K, in the vicinity of the band edge.



The Urbach edge grows as:

$$\alpha(h\nu) \sim \exp\{(h\nu - E_g)/E_o\},$$

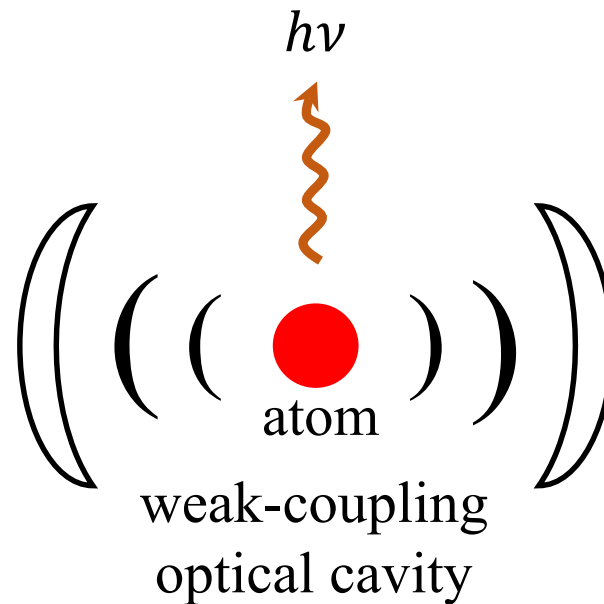
where the E_o parameter is a type of sub-threshold slope.

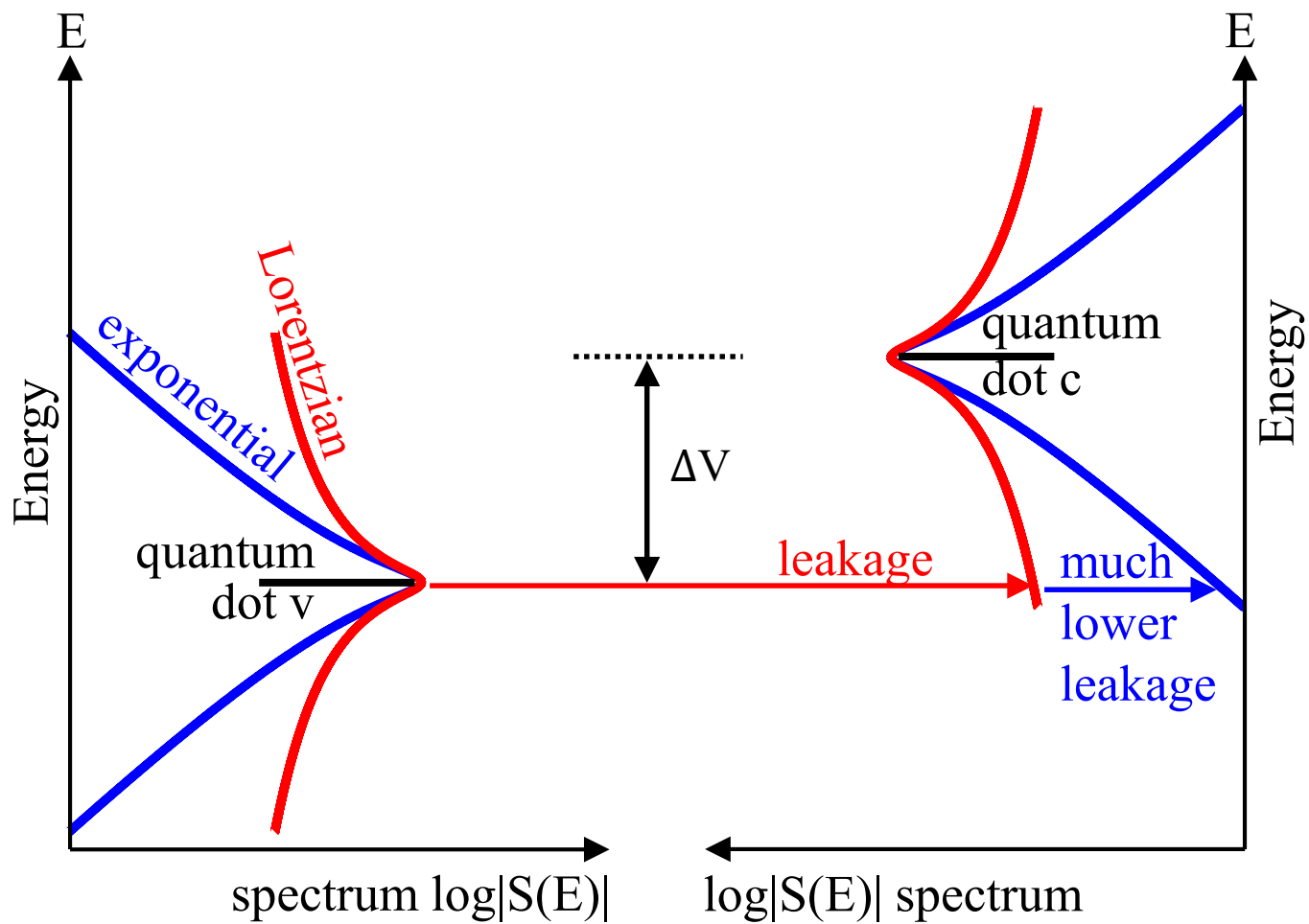
$$E_o \sim 10\text{meV for Silicon}$$

The Urbach Tail also explains why optical fibers are so transparent.

There is an analogy with weak-coupling of
an atom to an optical cavity.

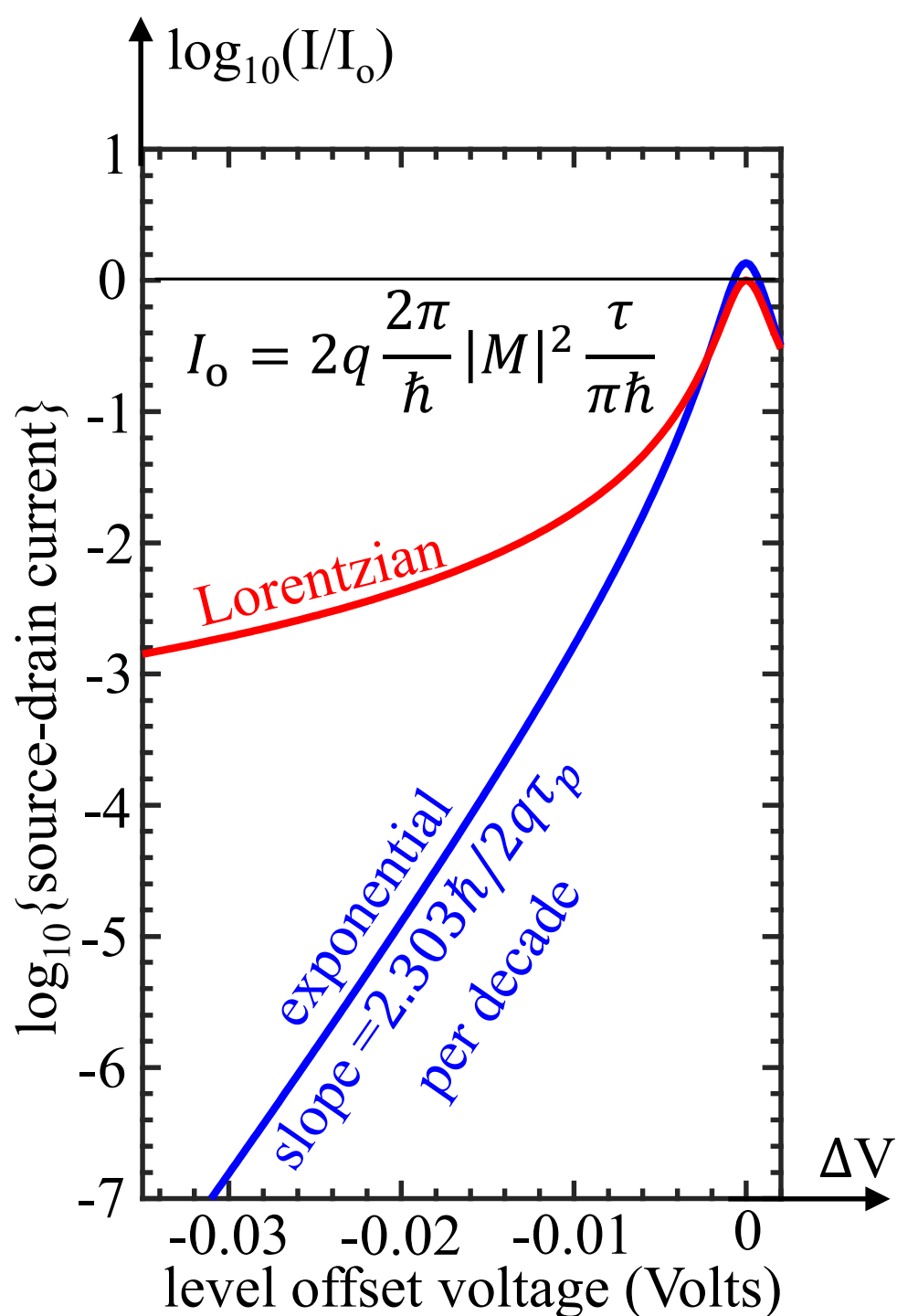
The initial atomic decay is predicted to be parabolic,
And the spectrum non-Lorentzian.





(b)

The predicted tFET
I-V curves.



- molecular synthesized structures

**Bottom-Up
Synthesis of
Atomically
Defined
Graphene
Nano-
Ribbon
Devices**



Fischer



Louie



Bokor



Yablonovitch

**Prof. Felix Fischer
Prof. Steven Louie
Prof. Jeff Bokor
Prof. Eli Yablonovitch**



□ Chalcogenide Mono-Layers:



Javey



Jing Kong



Yablonovitch



□ Single Nano-Wire tFET's:



Del Alamo

