We1F-3

A Compact and High-Power Frequency-Selective Plasma Limiter with an Ultra-High Isolation

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Motivation

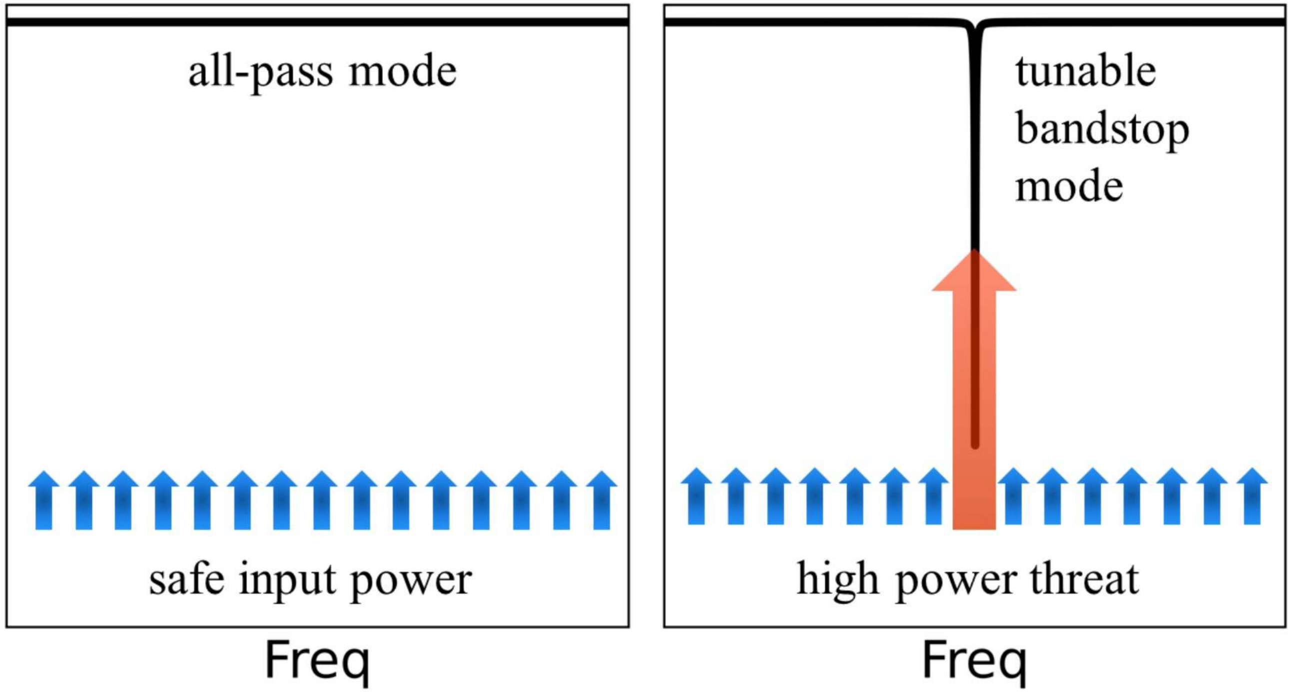
HEM/EMP

- instantaneous, and intense electromagnetic fields
- disrupt electrical systems and high technology microcircuits.

Solutions for defending electronic systems

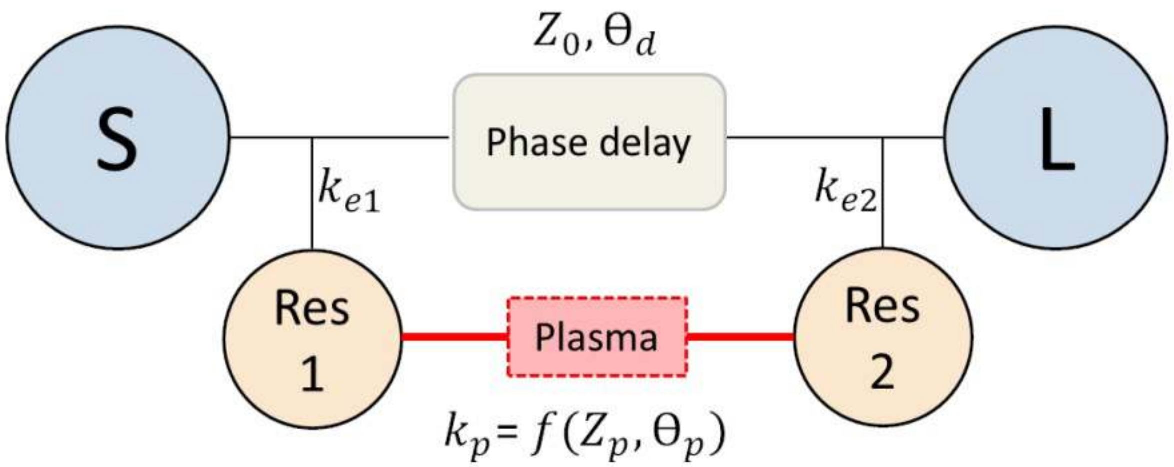
- reconfigurable and selective limiters
- allow system to function over safe frequency bands
- block bands that pose high-power threats.

Ideal FSL Characteristics



- Existing FSL Technology
  - Ferromagnetic, Semiconductors, Phase change, Multiplexer and Filter
  - Wideband rejection, Power handling, Insertion loss, Reconfigurability

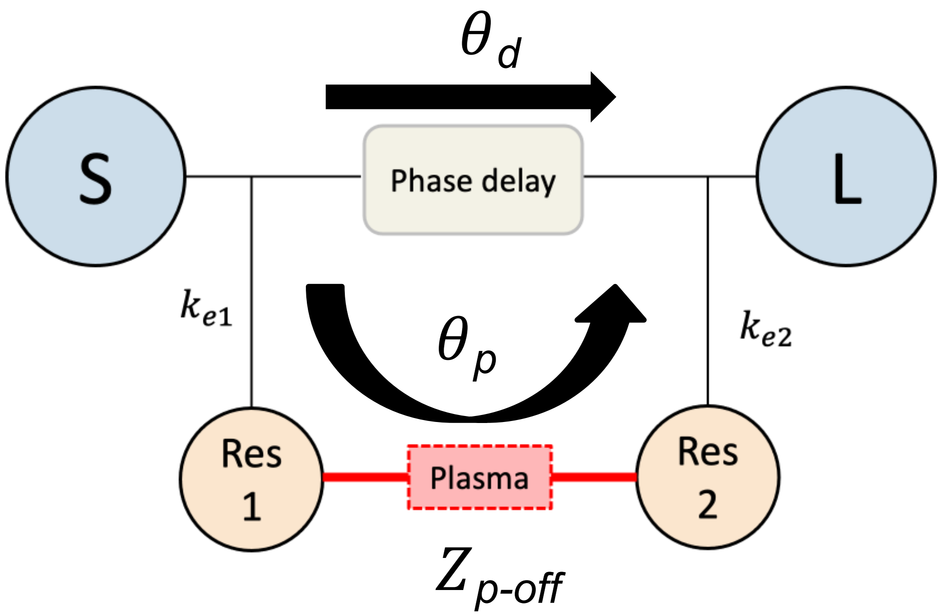
Proposed Topology



- Absorptive Filter Topology
  - High isolation and selectivity using low-Q resonators
  - Plasma based inter-resonator coupling

Proposed Topology

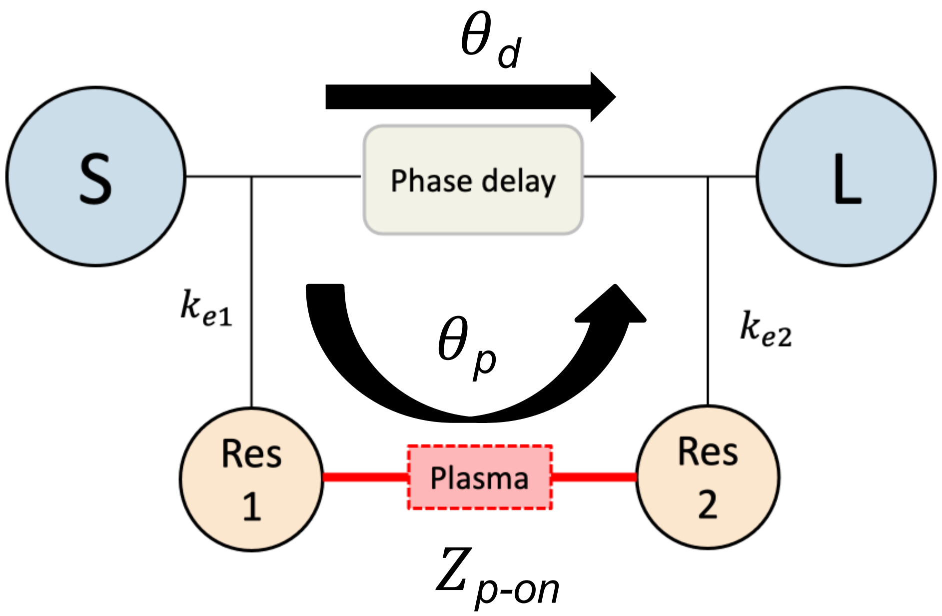
Safe Power



- Constructive Interference

$$\theta_p - \theta_p \quad = \quad 0\ deg$$

High Power threat

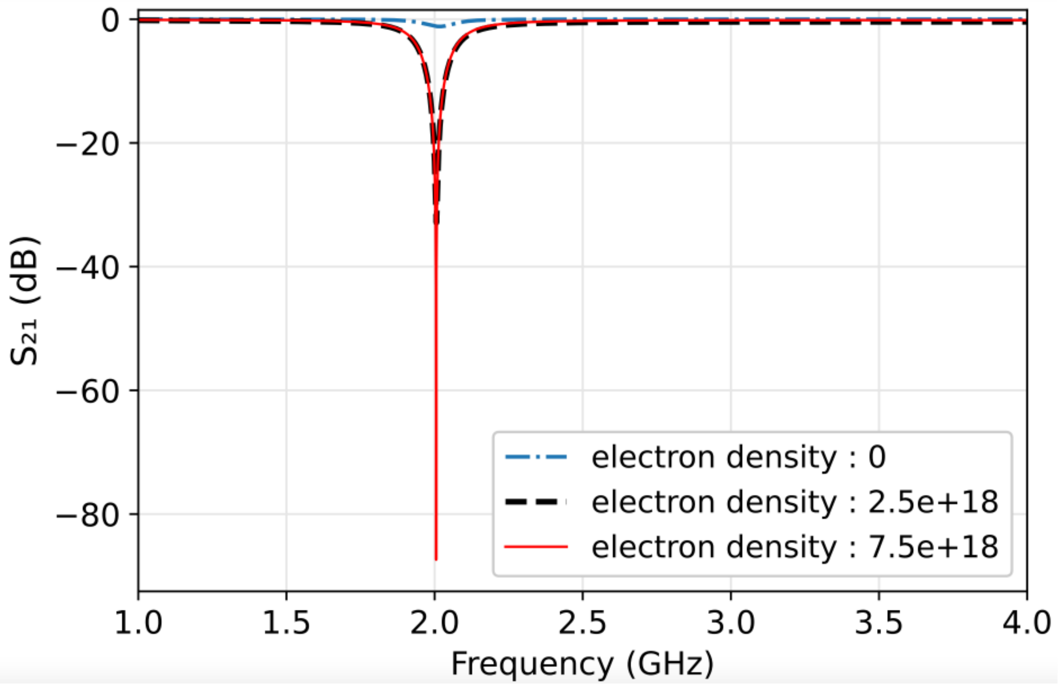


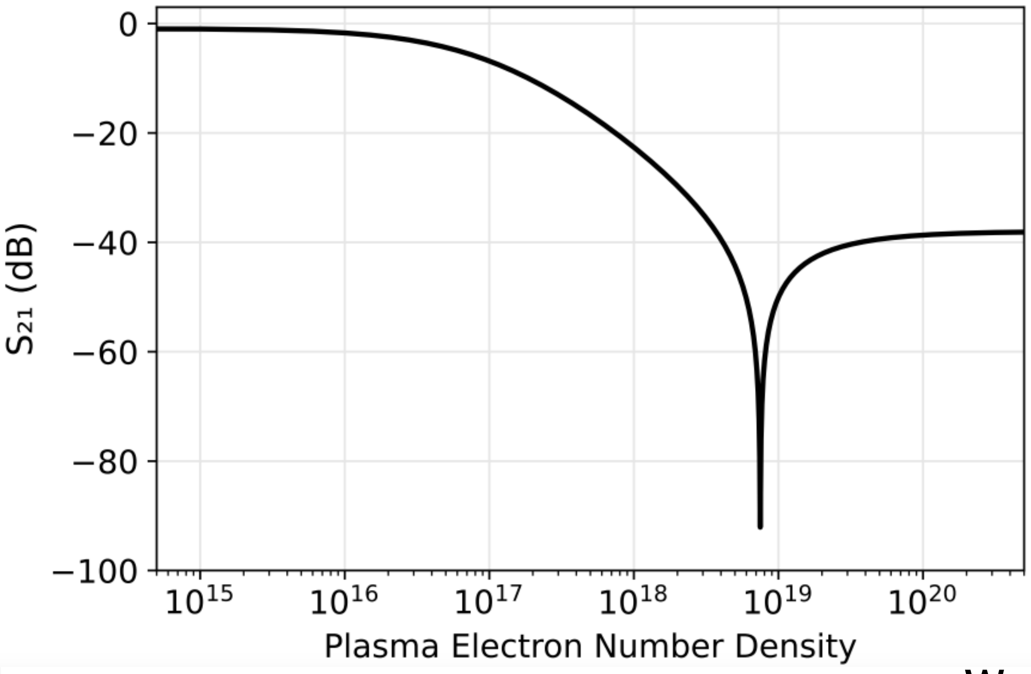
- Destructive Interference

$$\theta_p - \theta_p \quad = \quad 180\ deg$$

Theoretical Analysis

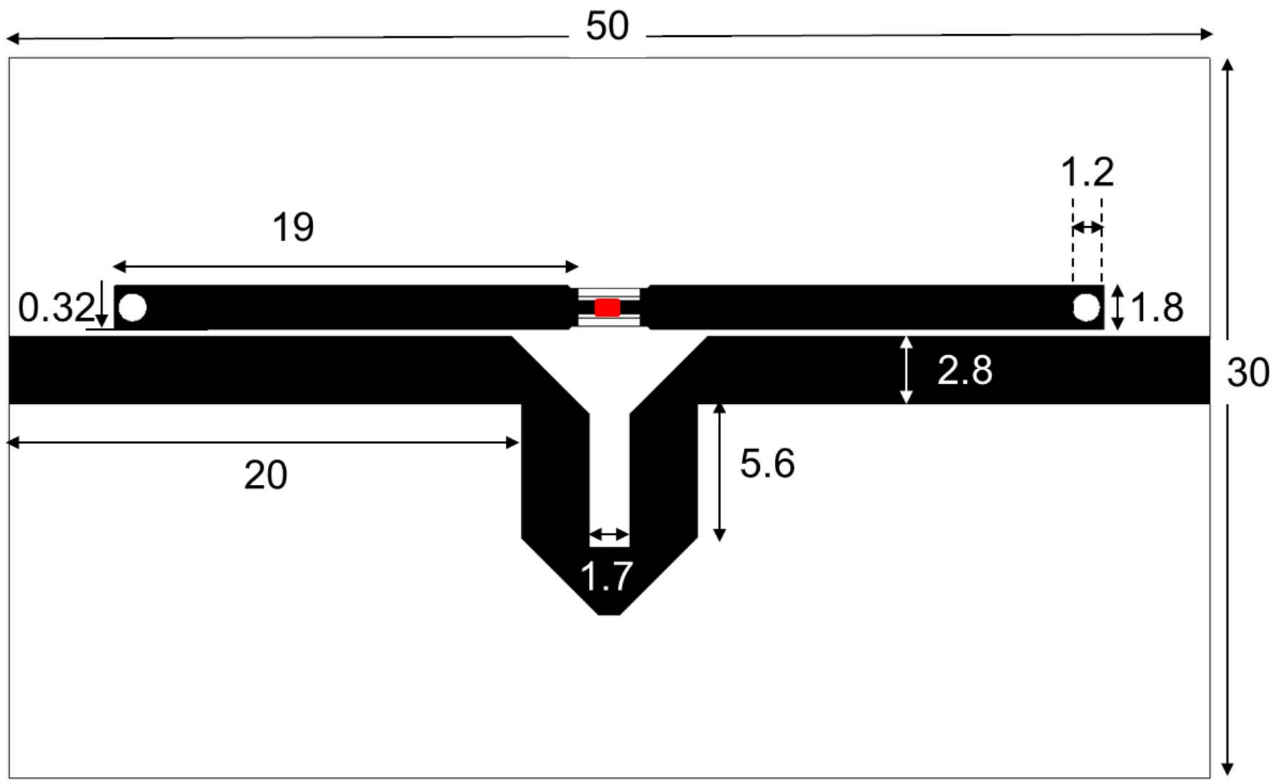
- ABCD Analysis
  - derive equivalent S Parameter Matrix of device
  - optimize k_e and θ_d for Plasma OFF and ON



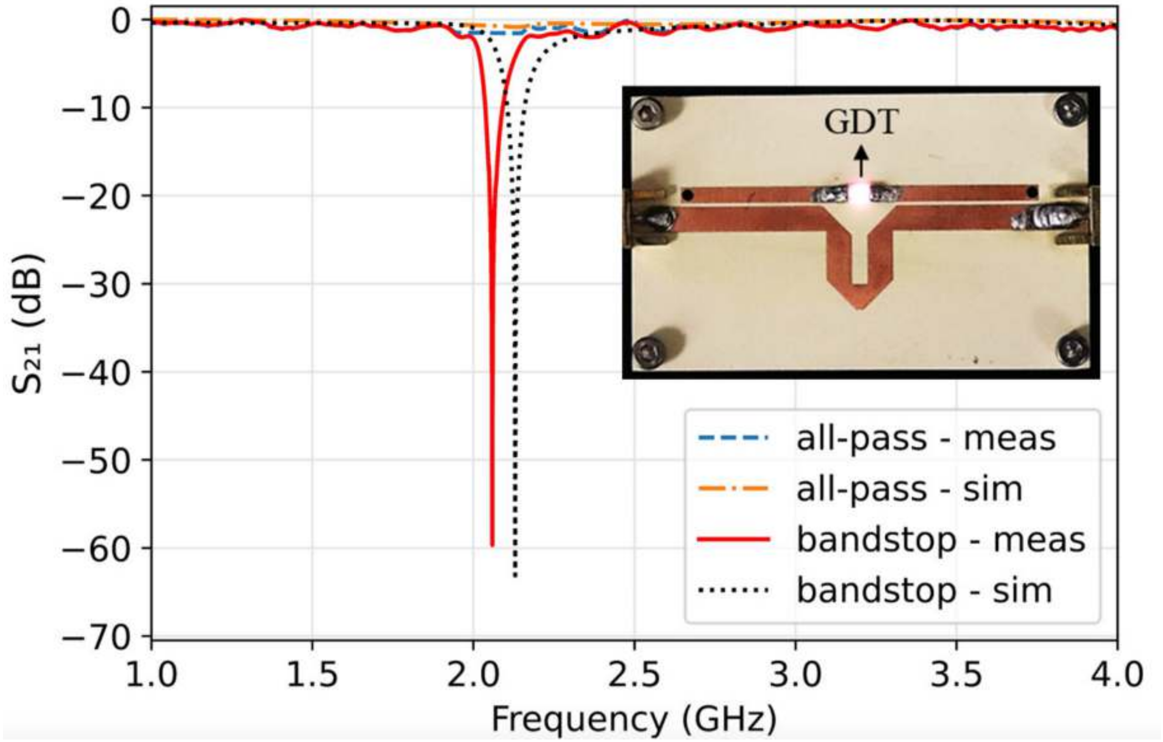


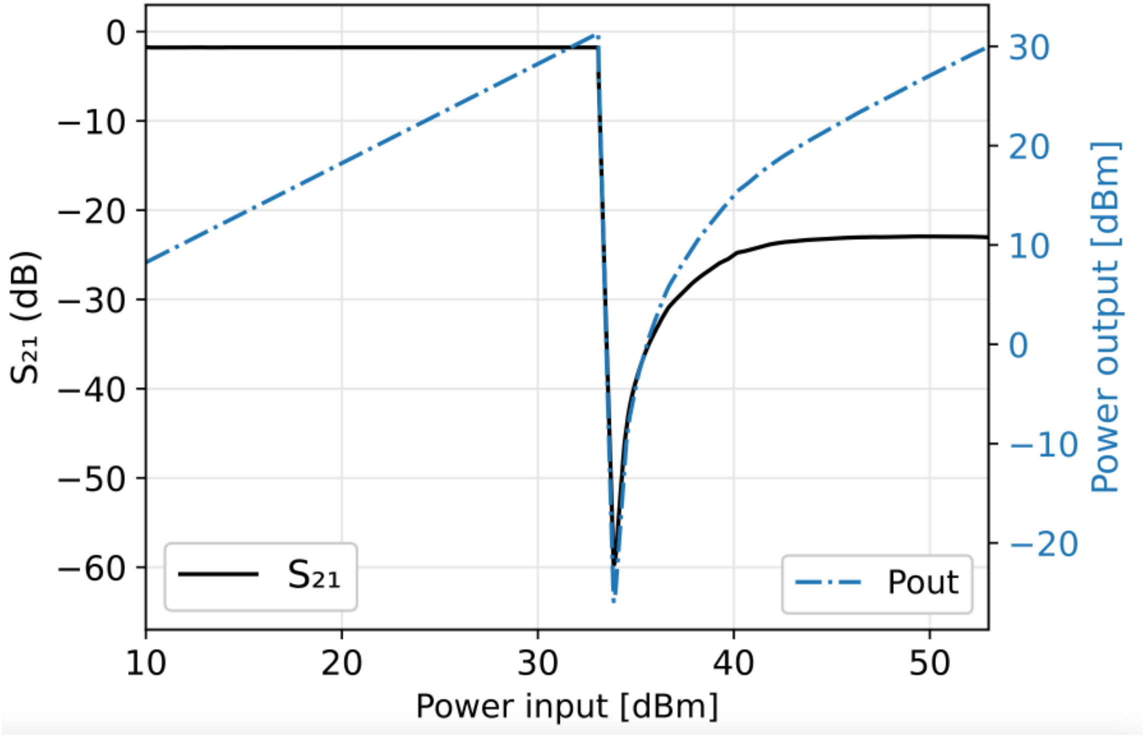
Proof of Concept FSL

- **Fabricated Prototype**
  - Rogers TMM4 board ($\varepsilon_r = 4.5$, $\delta = 0.01, h = 1.52$ mm)
  - Quarter-wavelength planar microstrip resonators ($Q = 200$)
  - Littelfuse SE140 as Plasma Shell ($V_{dc} = 140$ V)



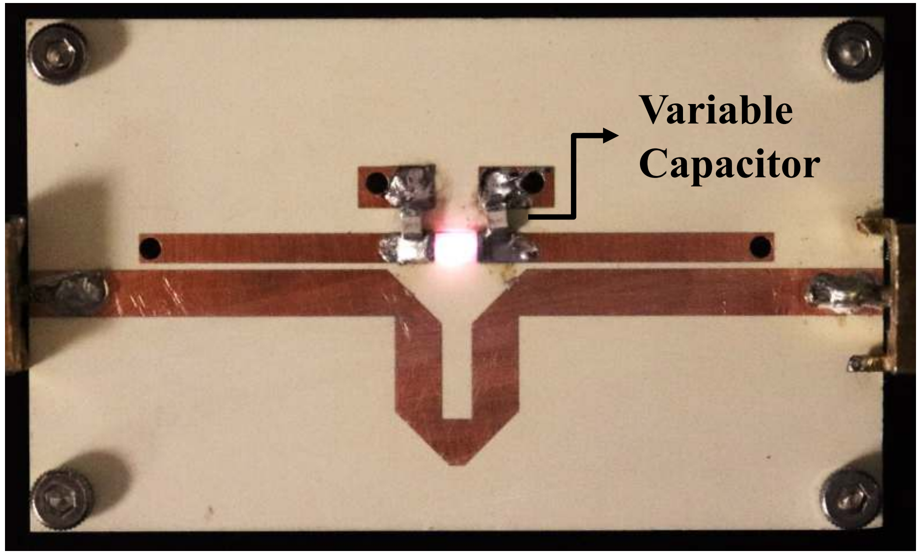
Static FSL

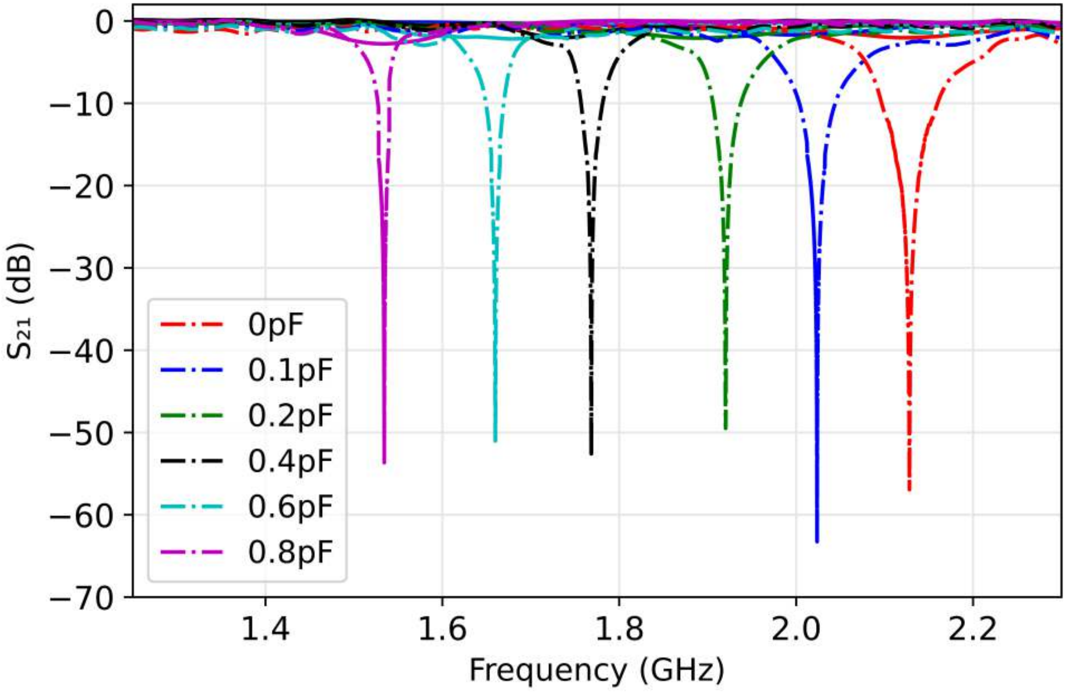




- $P_{th} = 34.5$ dBm , IL = 1.5 dB, 10 dB FBW = 2.8%

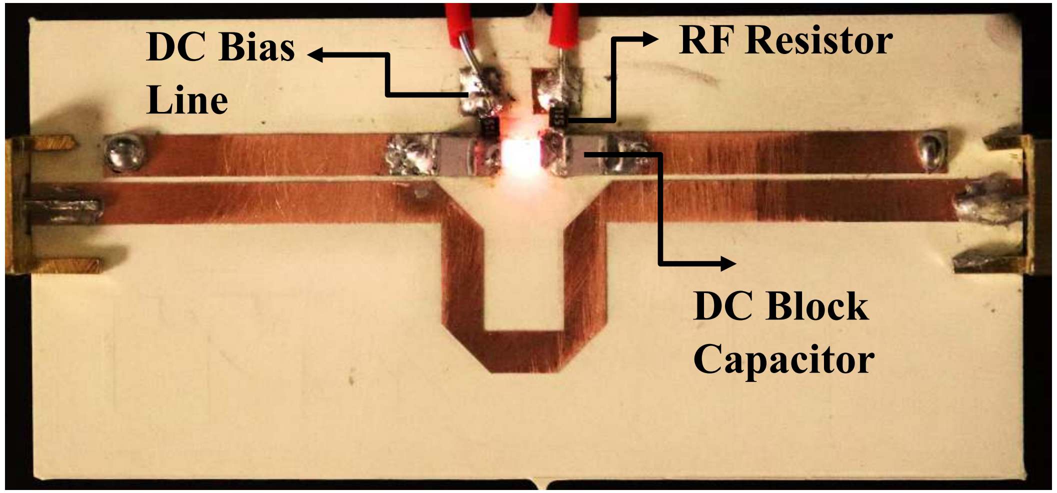
Frequency Tunable FSL

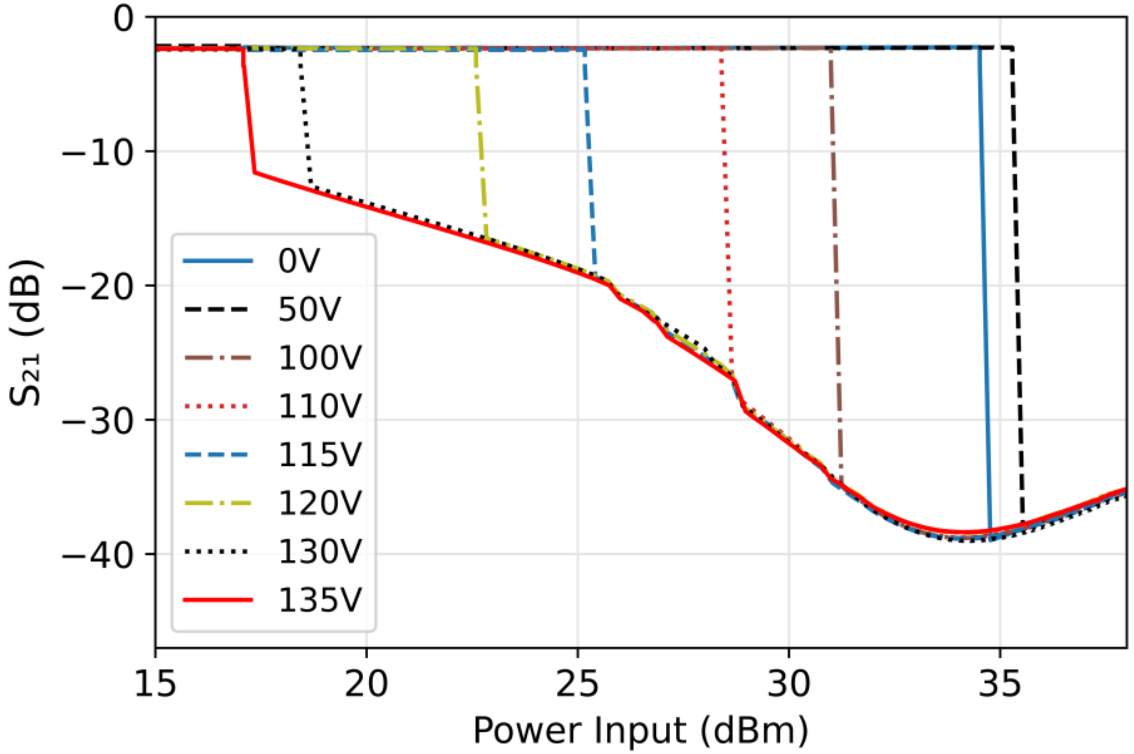




- Capacitor range = (0 – 0.8 pF), Frequency tuning = 600 MHz, 10 dB FBW = (1% - 2.7 %)

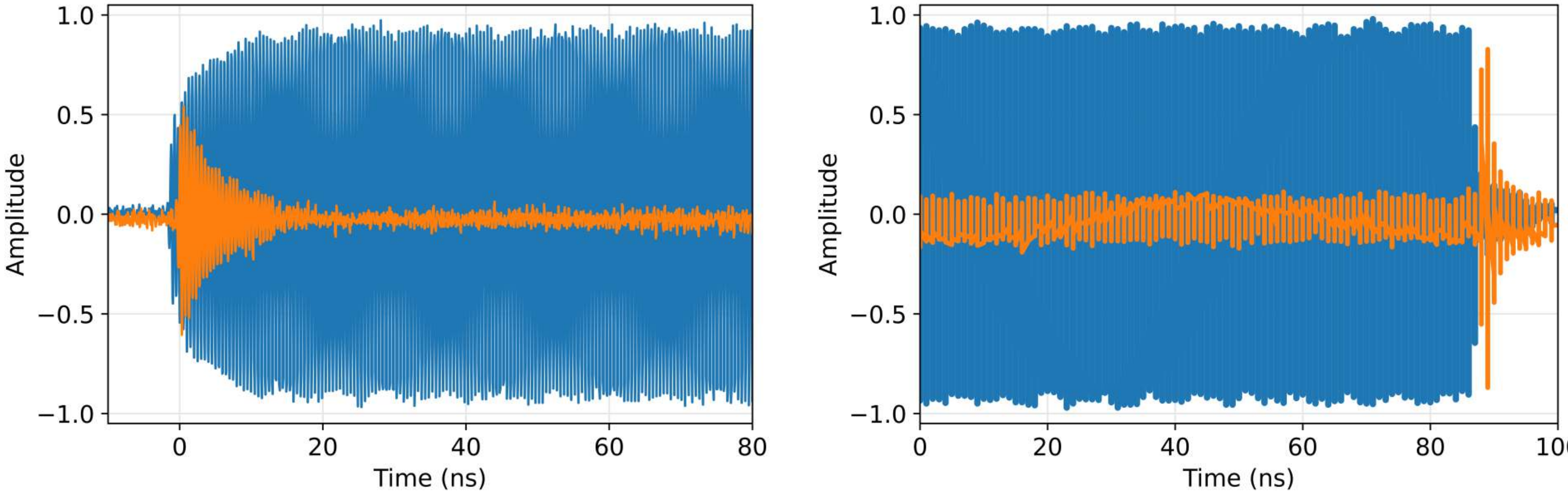
Power Tunable FSL





- DC Bias provides seed electrons for pre-ionization and reduces Microwave Power required for breakdown
- DC Block Capacitor and RF Resistor separates DC and Microwave signals. Power Tuning Range = 19 dBm

Response and Recovery Time



- Crucial in high-power systems.
- RT < 10ns

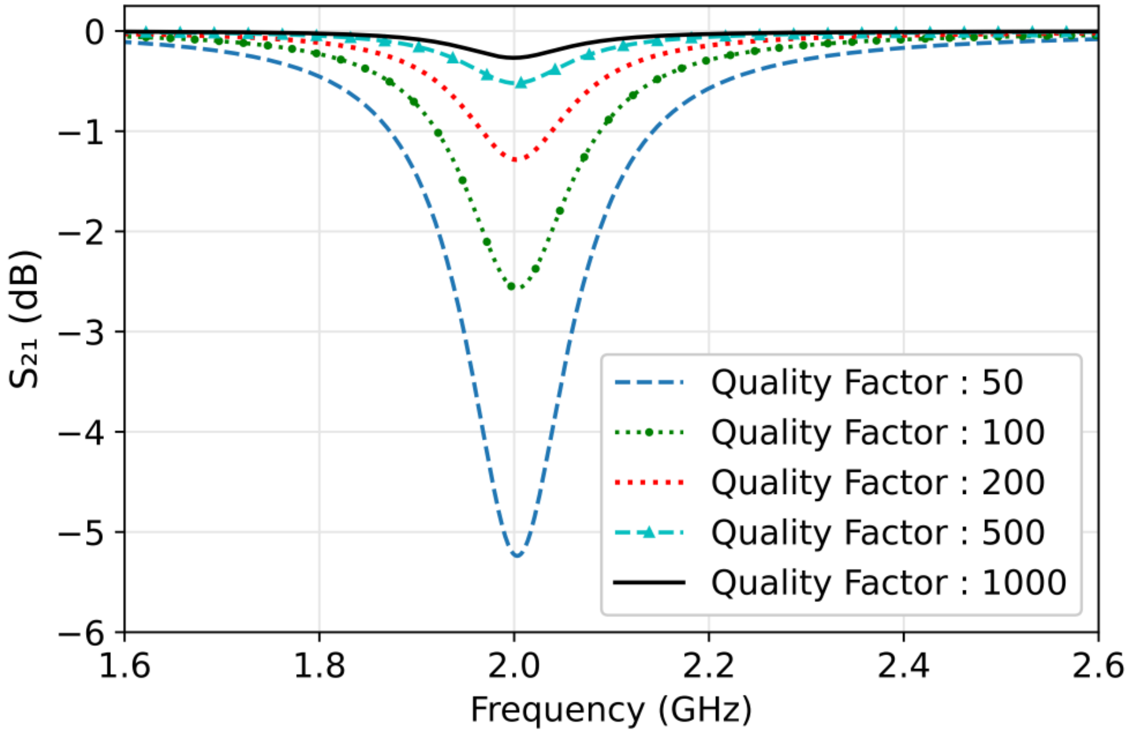
Comparison with State of Art

	Technology/ Topology	Power handling (dBm)	Isolation (dB)	Insertion loss (dB)	Response time	Power tuning (dBm)	Frequency tuning
[2]	Diode	42	22	1	10 ns	No	No
[5]	Phase change	40	15 - 40	0.7	4 μs	6	No
[6]	Phase change	25	16	1.5	N/A	No	No
[8]	Parametric	30	17	0.8	200 ns	No	No
[10]	Magnetic	35	11	4	200 ns	No	No
[11]	Triple Mode	45	45	3.1	N/A	58	1.5 - 2 GHz
[13]	Bandstop	20	18	2	10 ns	No	No
[15]	MNRC	15	7.5	3.5	17 ns	No	7.5 - 12.5 GHz
[16]	Multiplexer	38	22	1.8	10 ns	17	1 - 1.3 GHz
[17]	Plasma	50	35	1.6	10 ns	10	No
This work	Absorptive plasma	52	60	1.5	10 ns	19	1.55 - 2.15 GHz

- Outperforms all the state of art devices in power handling, bandstop isolation and reconfigurability.
- IL can be improved by using higher QF resonators

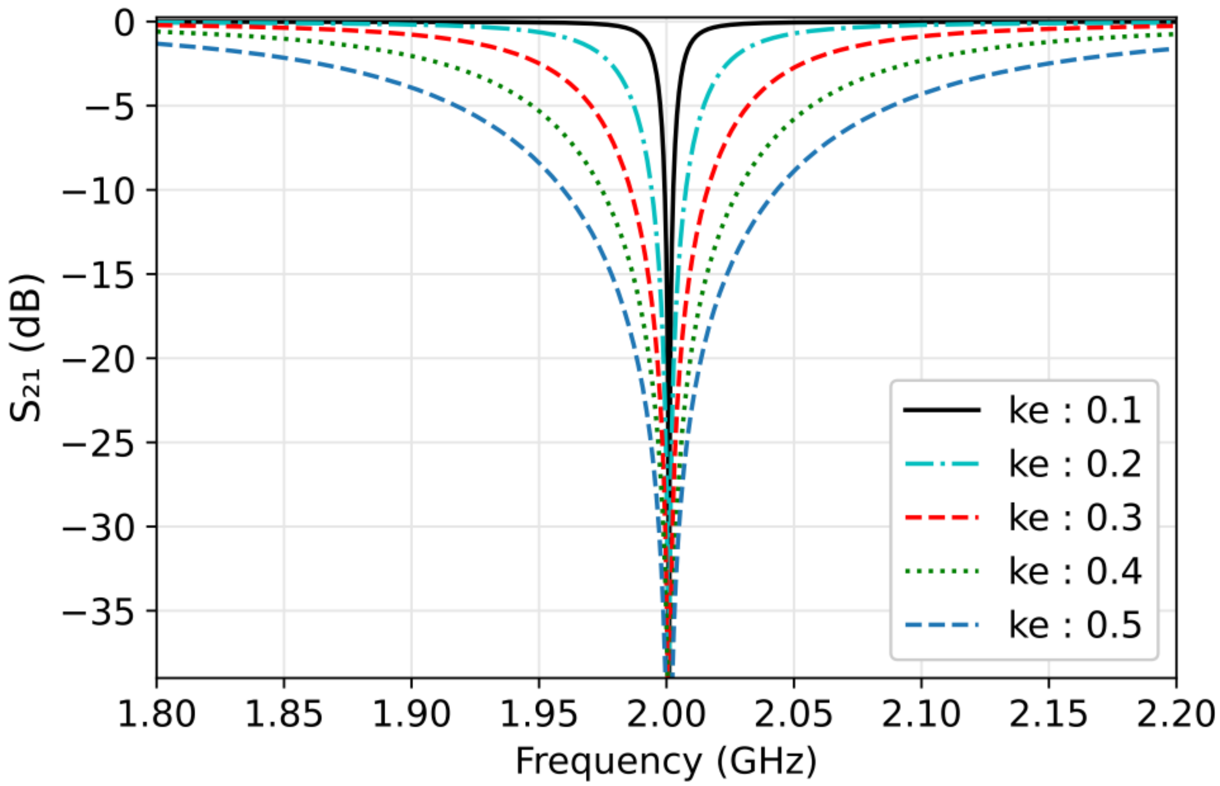
Additional Slides

Insertion Loss - FSL



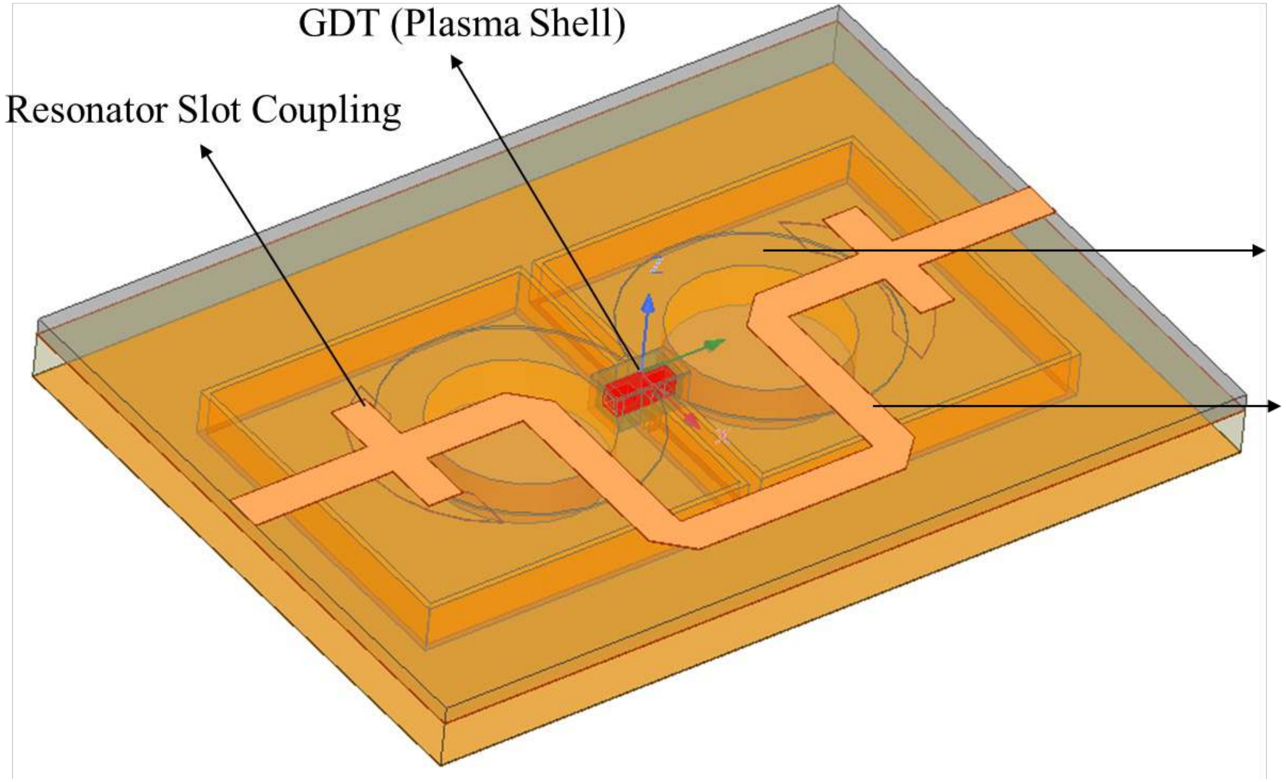
- All-Pass Insertion Loss as a function Resonator Quality Factor
- Cavity based Resonator is preferred for lower IL

Bandwidth Selectivity - FSL



- Bandwidth Selectivity as a function of External Coupling Coefficient
- Lower ke is preferred provided custom plasma shells are available

Future Work



- Plasma Based FSL employing EVA Cavity Resonators
- Lower IL is expected due to higher QF of the Resonator