The design optimization of the dielectric assist accelerating structure for better heat and gas transfer

Shingo Mori(KEK), Mitsuhiro Yoshida(KEK),

Daisuke Satoh(AIST)

Supported by JSPS KAKENHI Grant and
Mitsubishi Heavy Industries Mechatronics Systems Ltd.

Outline

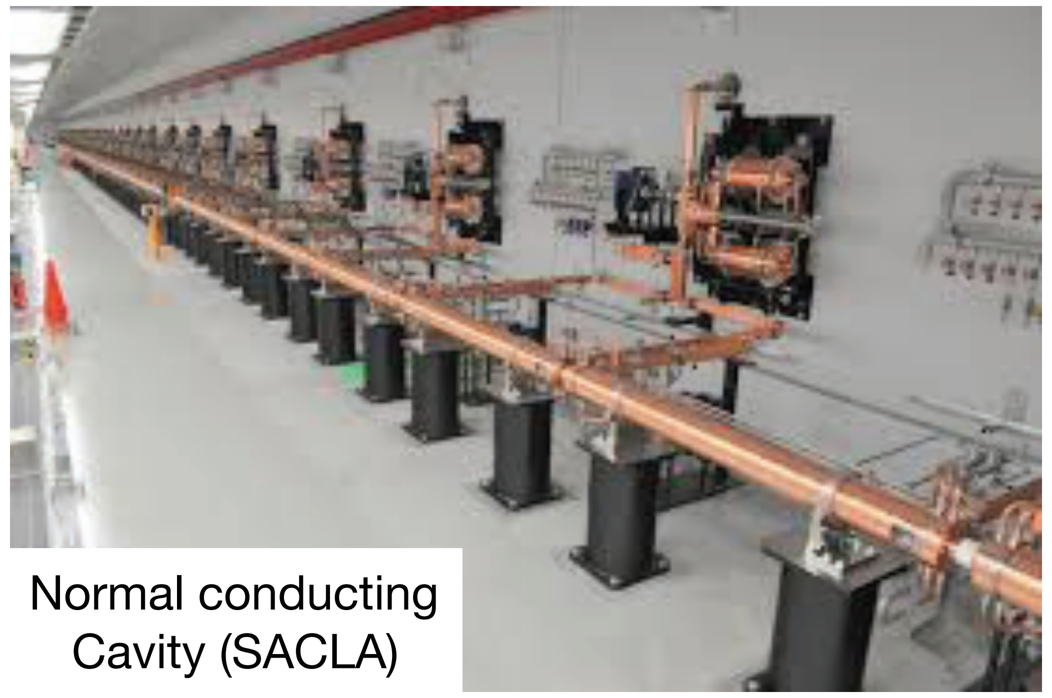
- Introduction:
  - Review of the dielectric-assist accelerating (DAA) structure
  - Expected impact of the DAA cavity
- Problems of the DAA cavity and Solution
- Simulation method and result
- Conclusion

Introduction

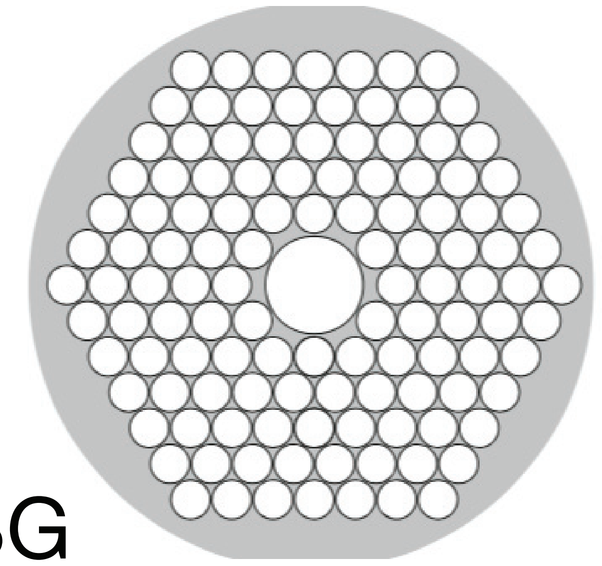
- Figure of merit of an accelerating cavity:

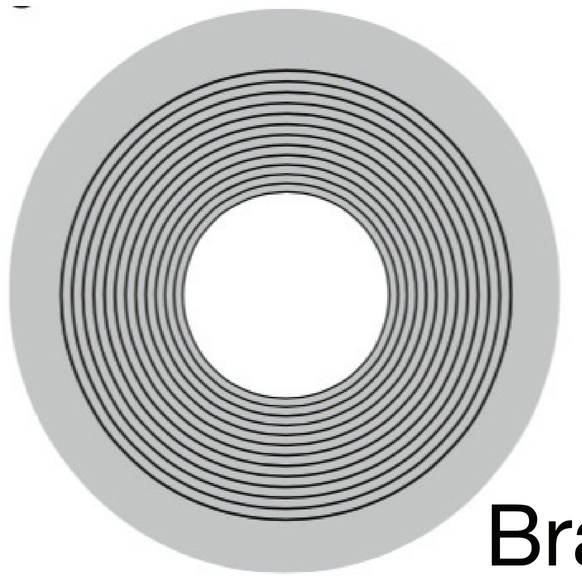
$$Q_0 = \frac{\omega U}{P_{\rm loss}}$$

- For conventional NC cavity: $Q_0 \sim 10^4 (@{\rm RT})$
  - 20MV/m → Ploss=40MW/m
- For SC cavity: $Q_0 \sim 10^{10} (@2{\rm K})$
  - 20MV/m → Ploss=40W/m
- For dielectric structure:


Normal conducting Cavity (SACLA)


Superconducting Cavity (cERL)


PBG


Bragg reflector

Skorobogatiy, Maksim. "Resonant Biochemical Sensors Based on Photonic Bandgap Waveguides and Fibers.",2010. 43-72.

If we can confine RF mostly in the dielectrics, Q0 is determined by material loss, $\tan\delta$.

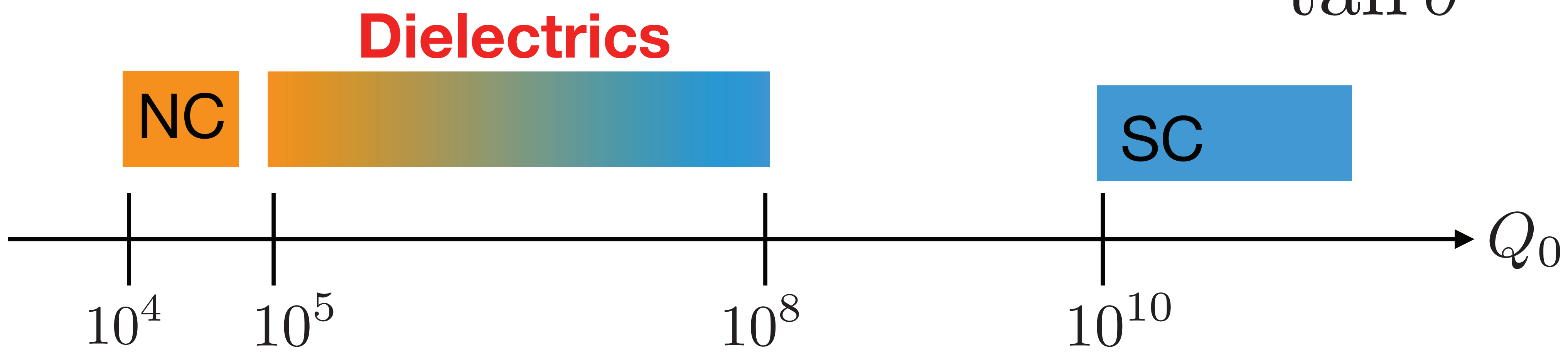
Introduction

✦ Dielectric cavity has potential of high Q value

Ex) sapphire has low-loss tangent:

$$\tan\delta < 10^{-8}(@\mathrm{T} < 50\mathrm{K}) \quad Q_0 \sim \frac{1}{\tan\delta} \sim 10^8$$

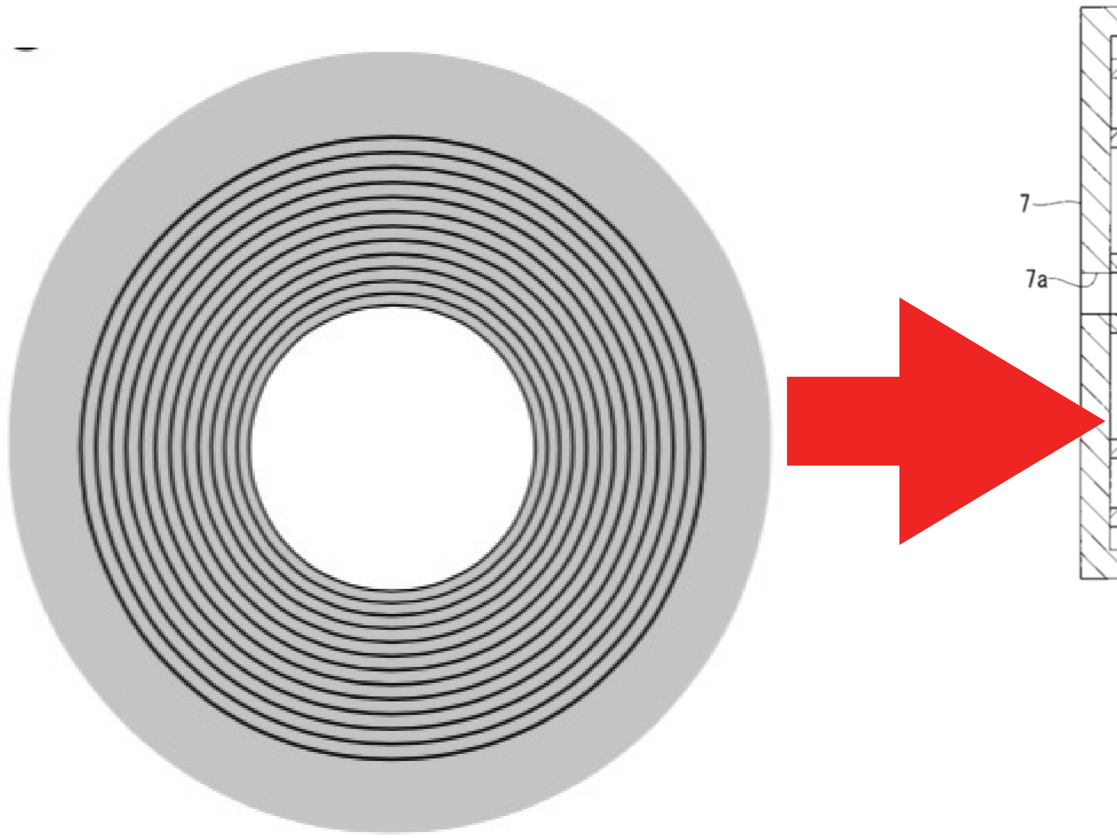
Braginsky, V. B., V. S. Ilchenko, and Kh S. Bagdassarov *Physics Letters A* 120.6 (1987): 300-305

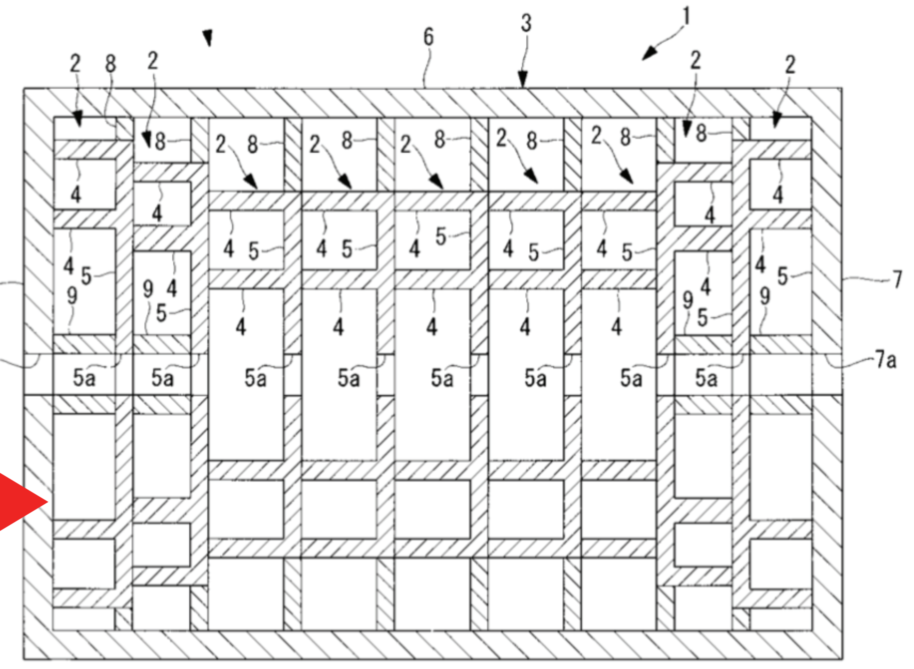


✦ Optical fiber

▶ **Dielectric-assist accelerating (DAA) structure**

Bragg reflector





ex) 2-layer case

Patent:JP2017-117730A

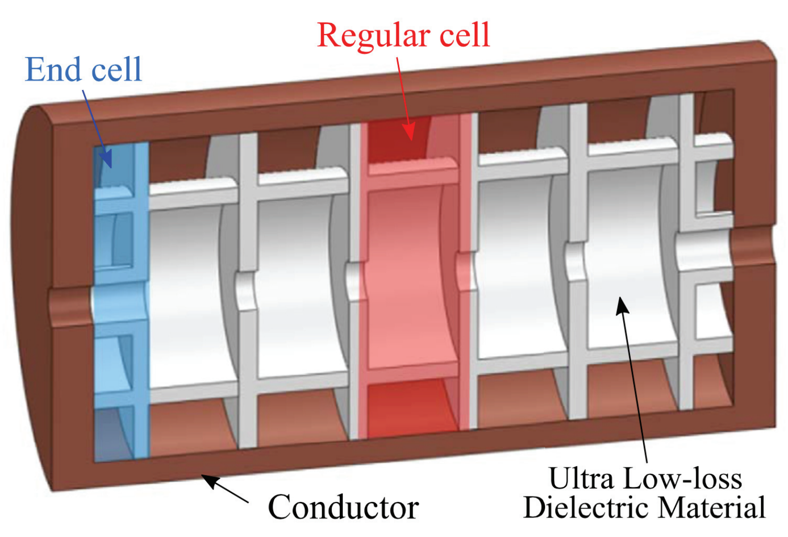
$$Q_0 > 10^7(@T < 100\mathrm{K}, 3\mathrm{Layers})$$

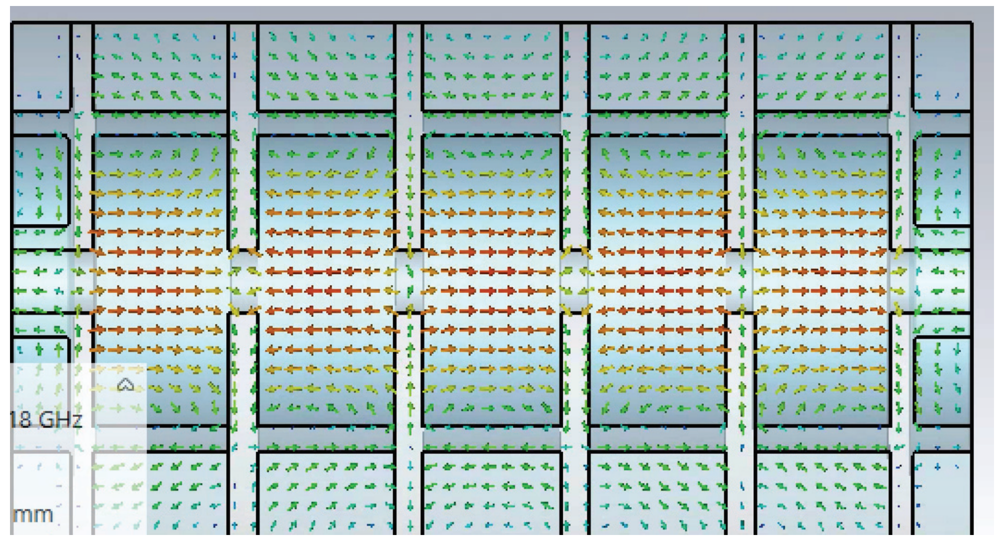
$$Q_0 \sim 10^5(@\mathrm{RT}, 1\mathrm{Layers})$$

Dielectric-Assist Accelerating Structure

JP2017-117730A, International patent

D. Satoh et al. (2016)



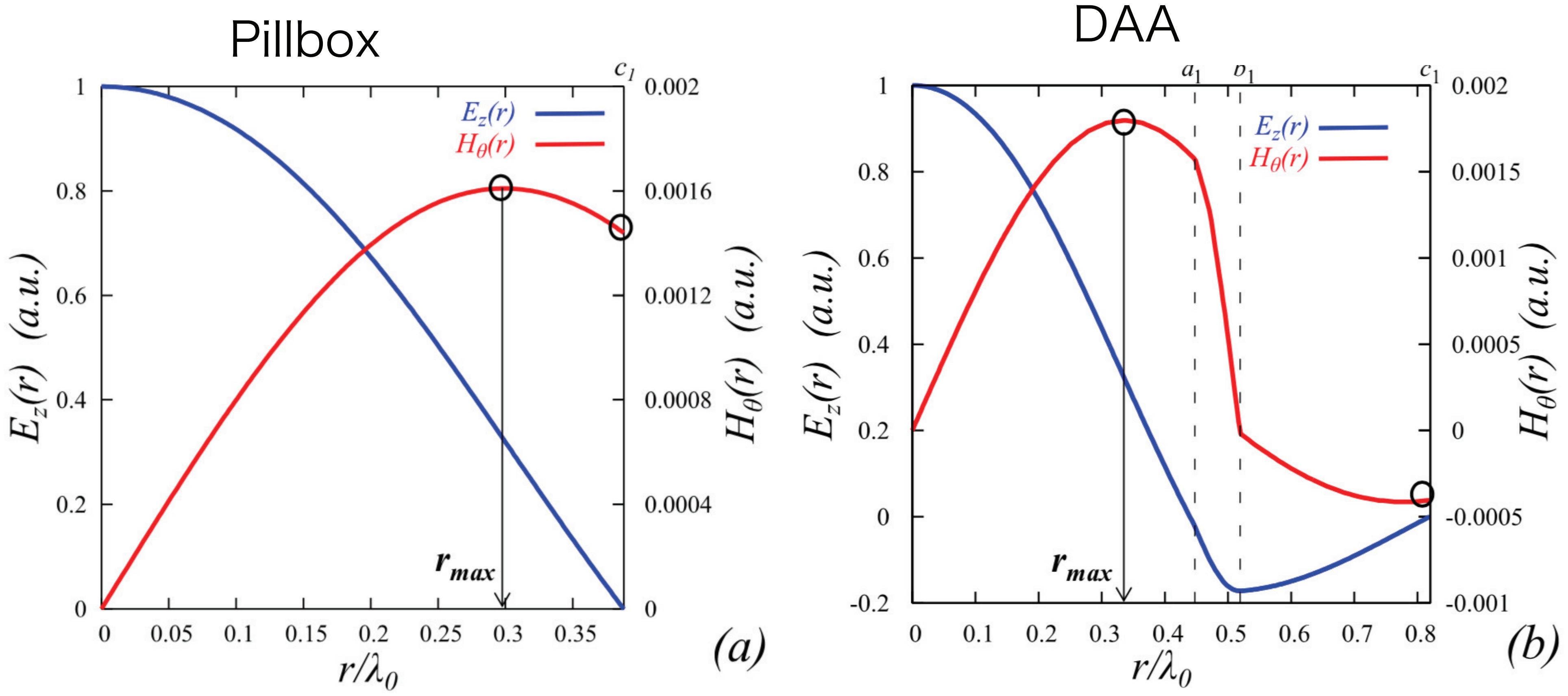


Center-field-enhanced TM026

$$Q_0 = \frac{\omega U}{P_{\mathrm{tot}}}$$

$$P_{\mathrm{tot}} = \frac{R_S}{2}\int_S |H|^2 dS + \frac{\omega}{2}\epsilon_r\epsilon_0 \tan\delta \int_V |E|^2 dV$$

Wall loss　　Dielectric loss



Choose a low loss
Dielectric material

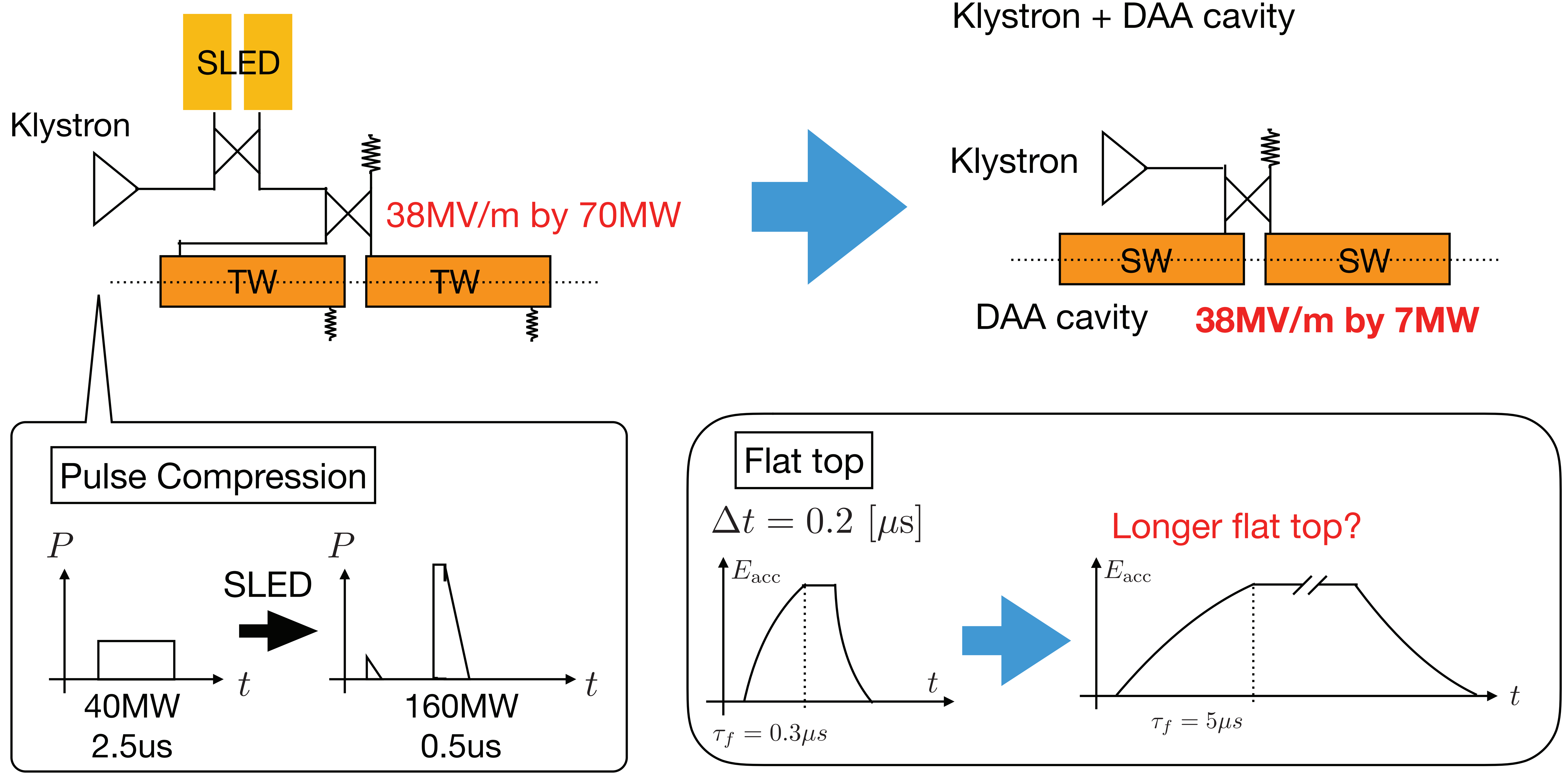
$\tan\delta = 6 \times 10^{-6}$
@RT

▶Even at room temperature, $Q_0 \sim 10^5$

▶x10 Q0 improvement is important!

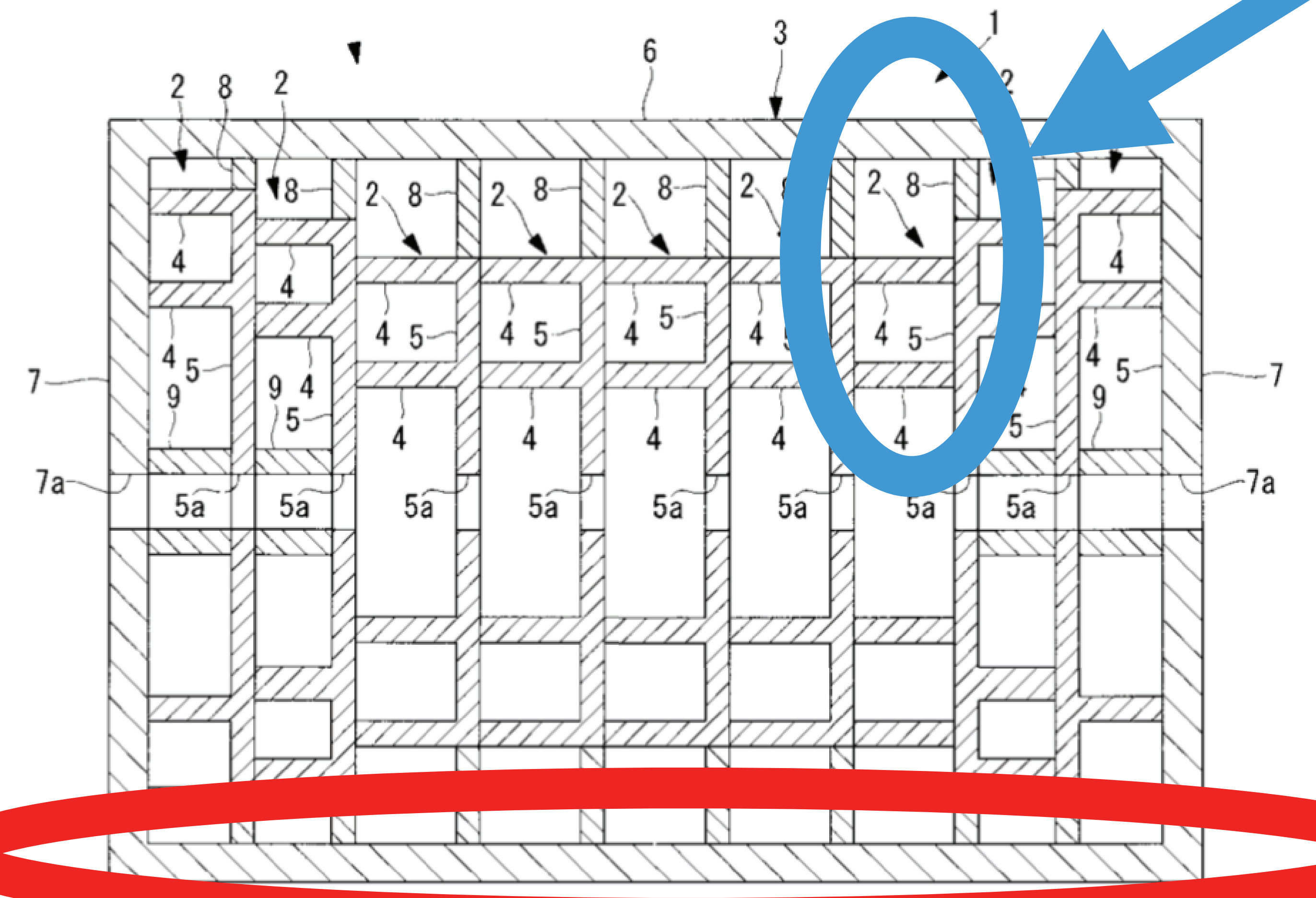
DAA accelerator does not need Pulse Compressor.
▶ Possibility of longer flat top!

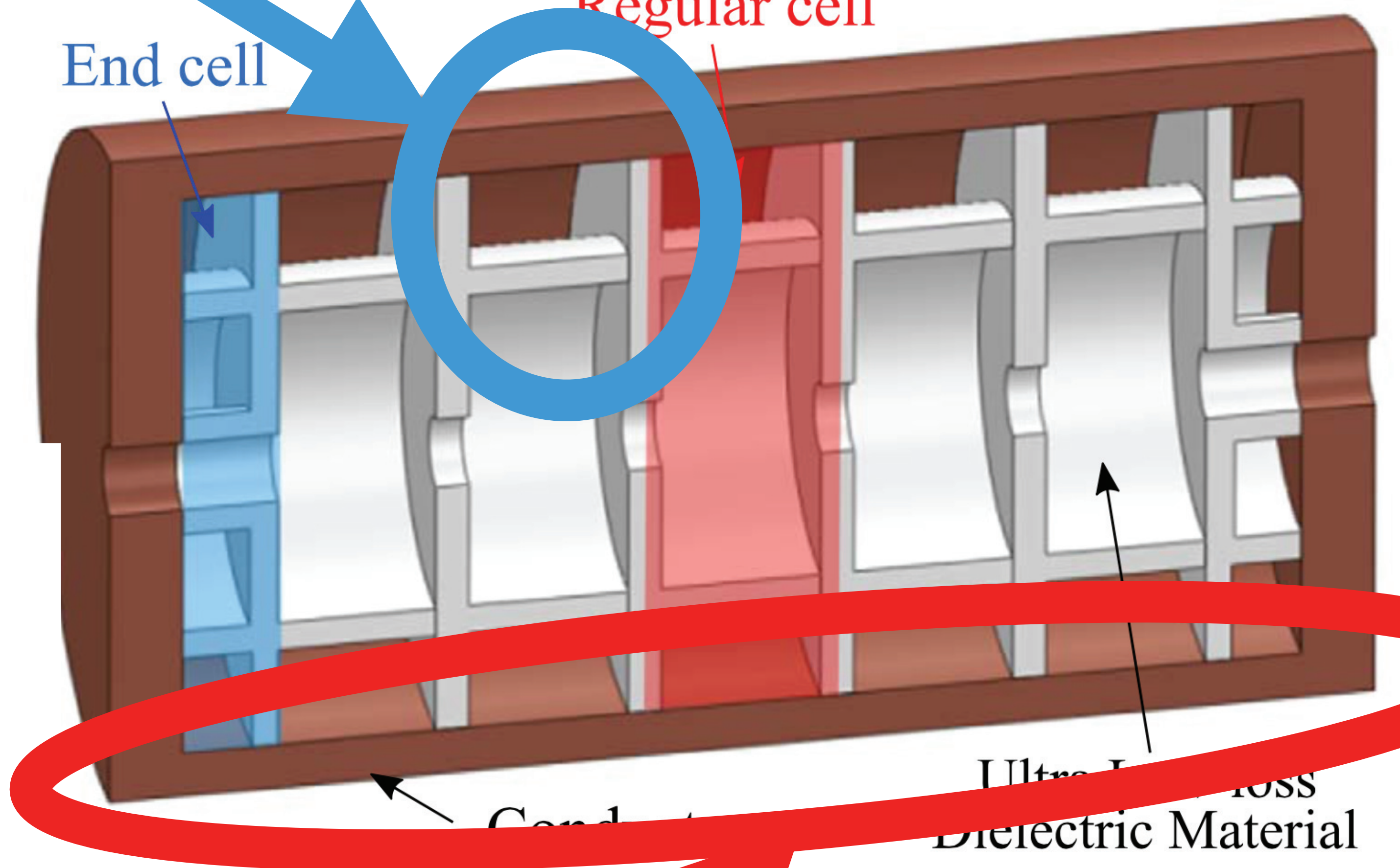
Ex)SACLA, Japan
Klystron + Pulse compressor + TW tube



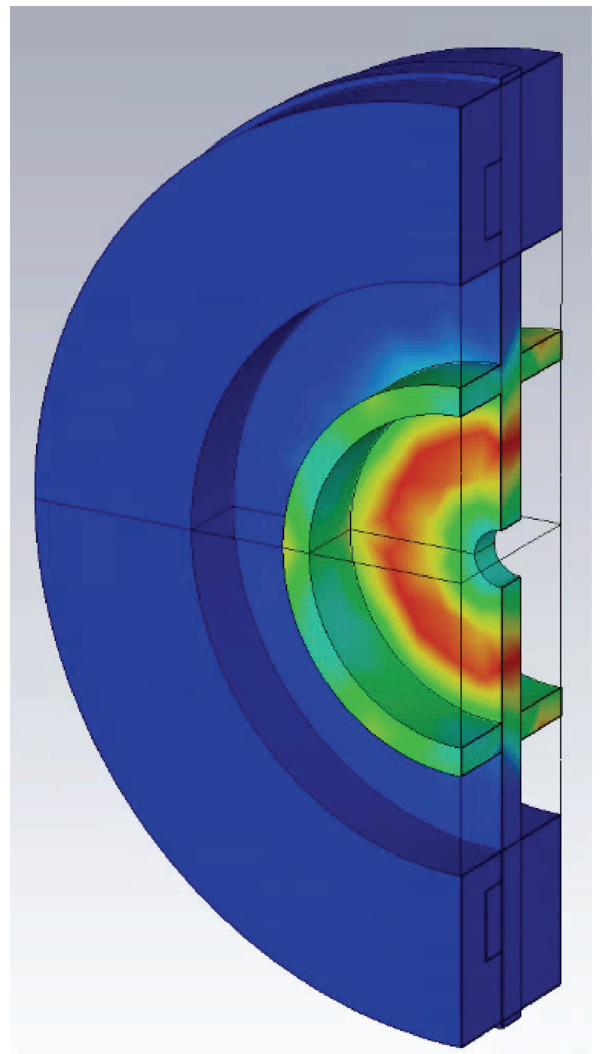
Problems of the DAA cavity

Evacuation!



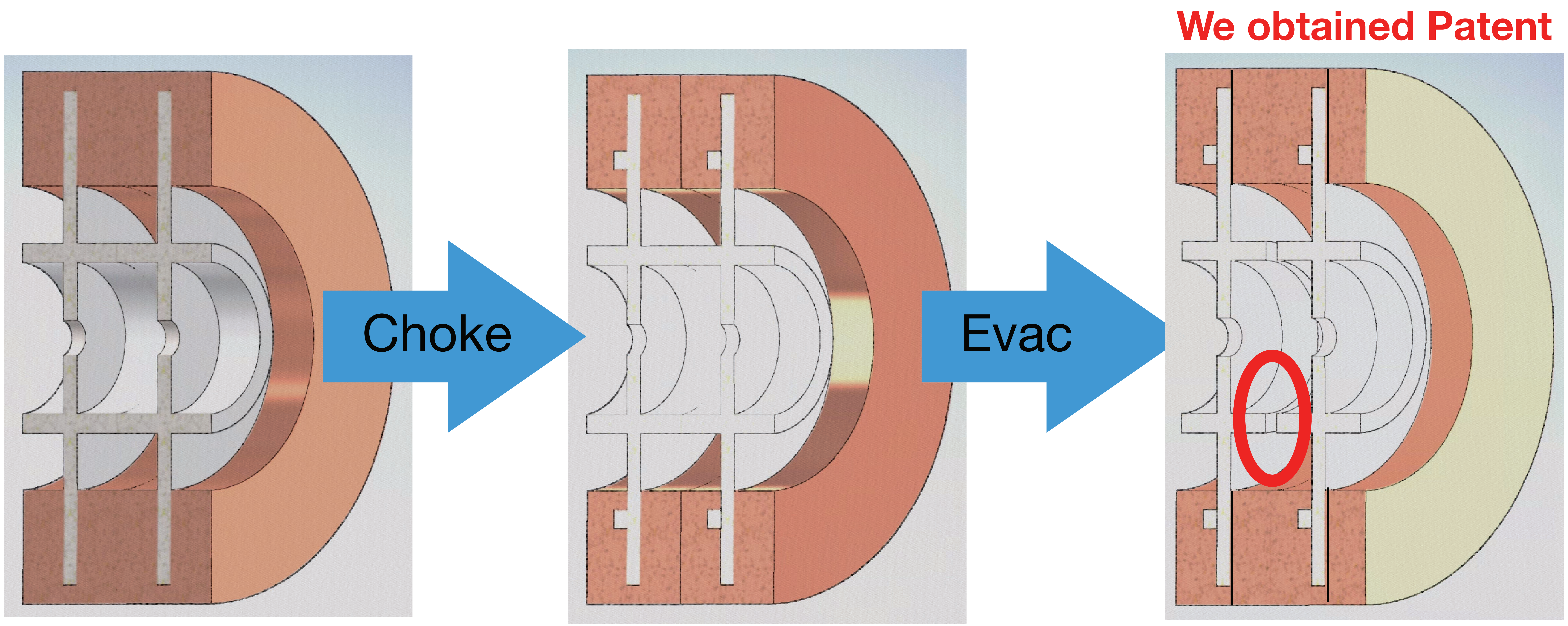


Contact!



Dielectric loss

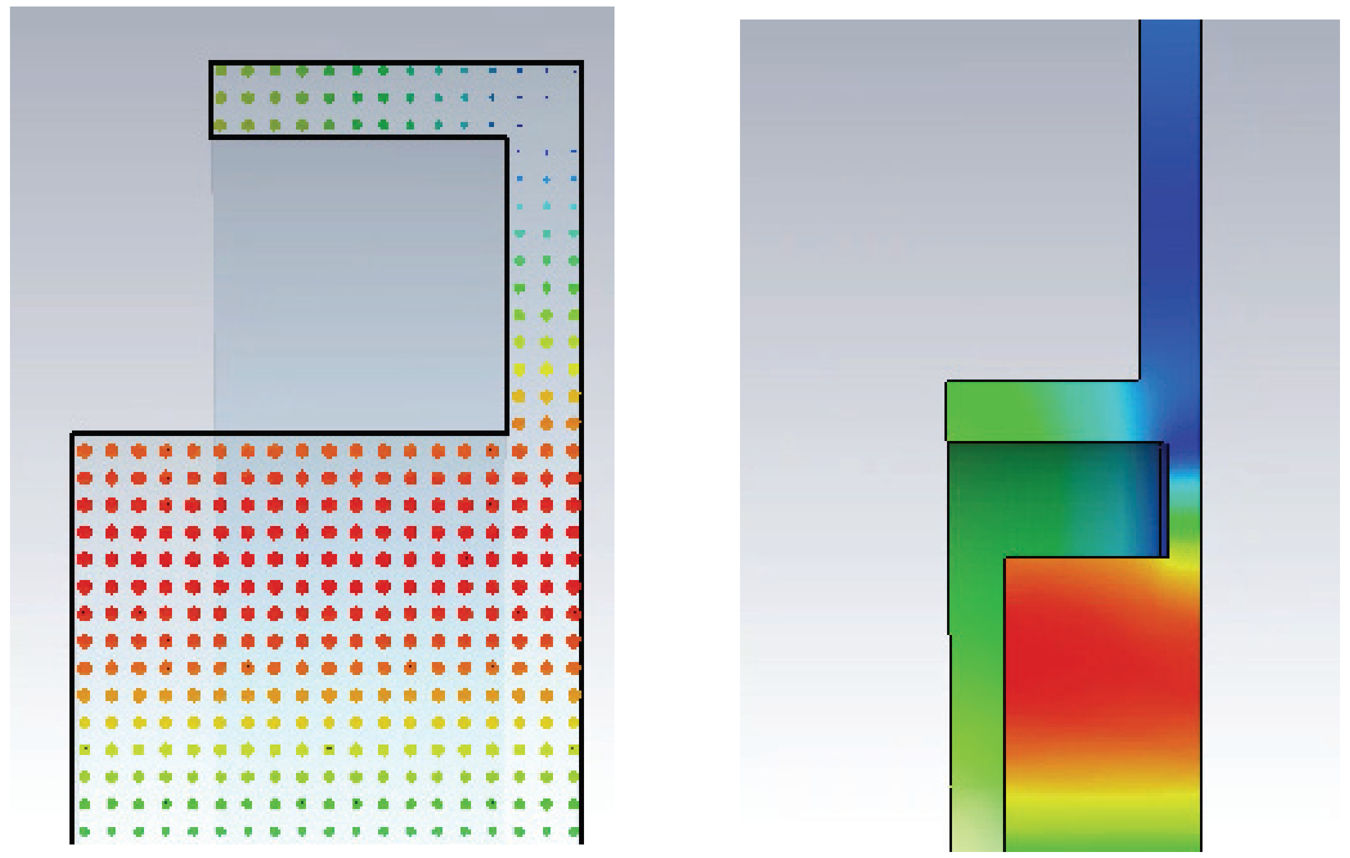
The simple solution to problems

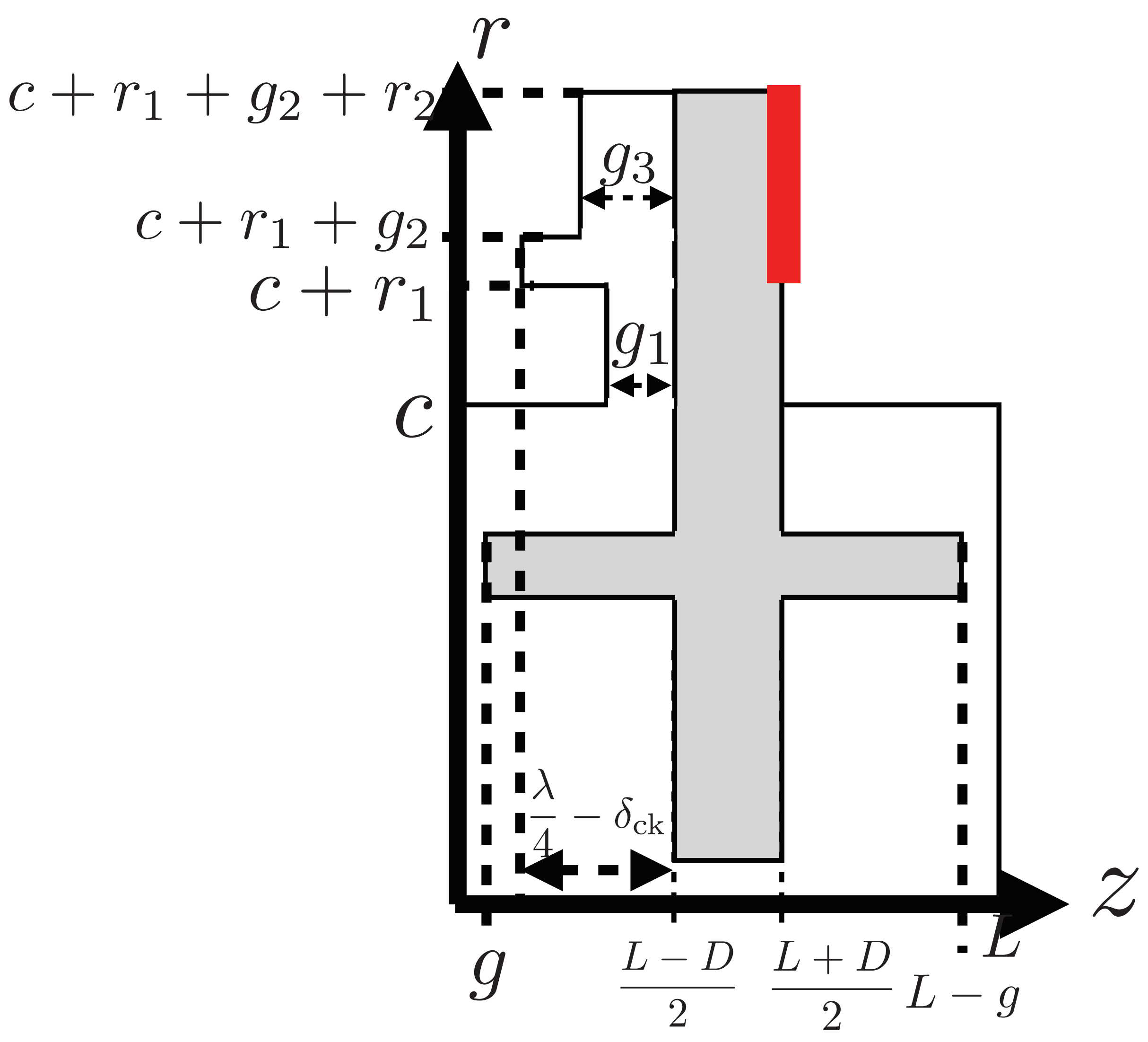


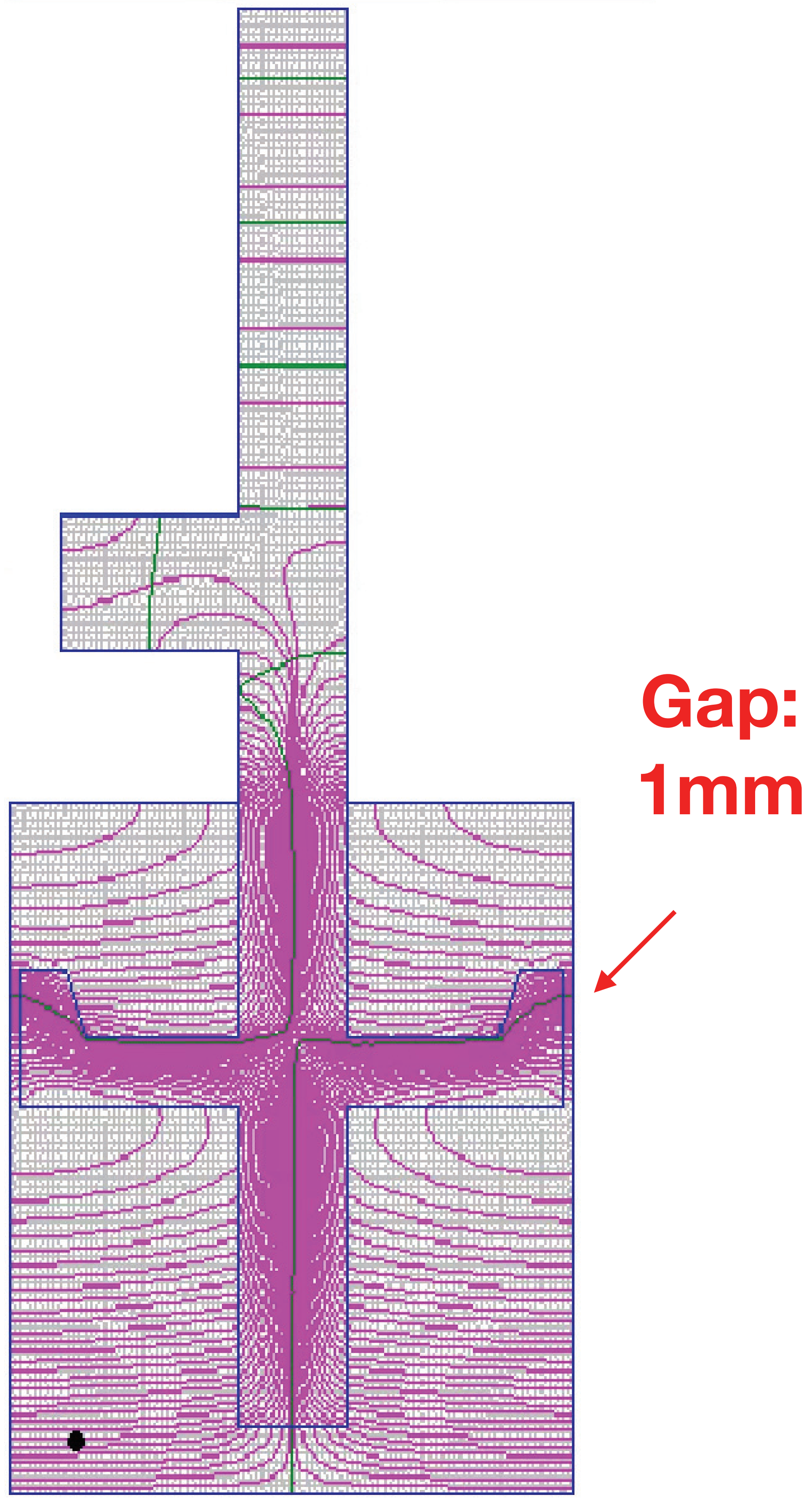
- ✦ The stacked structure ▶ longer standing wave tube
- ✦ Ceramics are fixed to the copper ring ▶ gap between ceramics
- ✦ Evacuation from beam hole in any number of layers

Simulation method and result

Ex) Pillbox with choke
Magnetic Field







✦ At the junction the wall current should be zero.

$$I_{\rm rad} \equiv \int_{c+r_1}^{c+r_1+r_2+g_2} dr H \Big|_{z=\frac{L+D}{2}-0}$$

$Q_0 = 1.21 \times 10^5$

$I_{\rm rad} = 0.175[A]$

Method:

1. Using SuperFish, we calculate configurations in the parameter space of r1, g2, δck.
2. Choose the configurations with higher Q0 value in top 10%.
3. Choose the configuration with lowest Irad.

- 8%Q0 decrease per 1mm separation of adjacent cells

Conclusion

- ✦ The DAA structure provides Q0~10^5 at room temperature, and can work without a pulse compressor.
- ✦ Since the contact between the ceramics and copper cavity has not been considered, we propose solutions to solve both the contact and evacuation.
- ✦ We show a solution to mitigate the problem of the thermal contact and evacuation from the side room.

In future work,

- ❋ After the fabrication of the new design, we need to measure the thermal resistance of the contact.
- ❋ We will consider the effect of the wakefield and the effect of the radial transmission line to reduce them.
- ❋ We need to mitigate the multipactoring between the narrow gaps in the cavity by coatings.