

Proposal of pilot search for axion in the micro-eV mass range with a stimulated resonant photon collider with X-band circularly polarized dual-frequency focused beams

Takafumi Miyamaru^{1,2}, Kensuke Homma^{1,3} and Tetsuo Abe⁴

μ SAPPHIRES collaboration

(Hiroshima Univ.¹, QUPIP², QUP³, KEK⁴)

Acknowledgement : QUP members

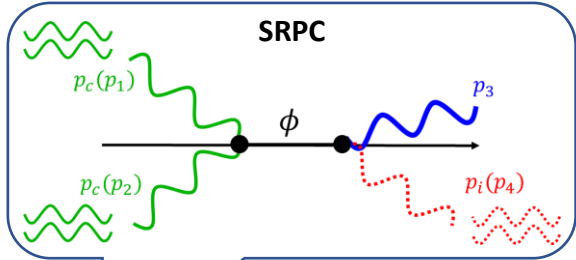
Masaya Miyahara, Masaya Hasegawa, Hiroki Akamatsu,
Satoru Igarashi(AES), Haruaki Hirose(YNU), Daisuke Kaneko,
Ryota Takaku, Hideo Iizuka, Suerfu Burkhan,
Ryota Hayakawa, Kaori Hattori

X-band photon collider concept

Ideal Gaussian microwave propagation focusing on free space

9 GHz
Inducing microwave pulse

GHz focus system



Focal point

11GHz detector

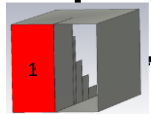
K. Homma et al., JHEP, 9(2020) 095

Parabola with a hole
Horn for signal photons

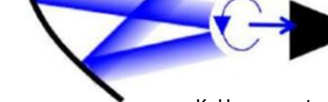
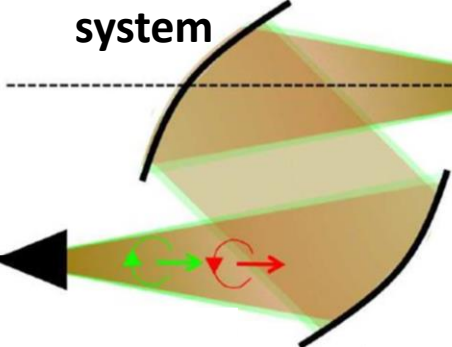
Dual frequency mixing
+
Opposite Circular polarization conversion

Selective collection of
large angle scattered signal photons

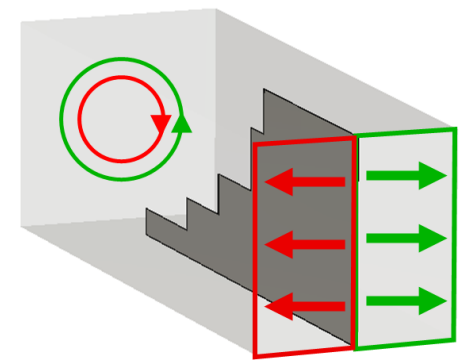
Circular-polarized
dual-frequency mixer



Creation microwave pulse
10 GHz



Septum-type circularly polarized mixer



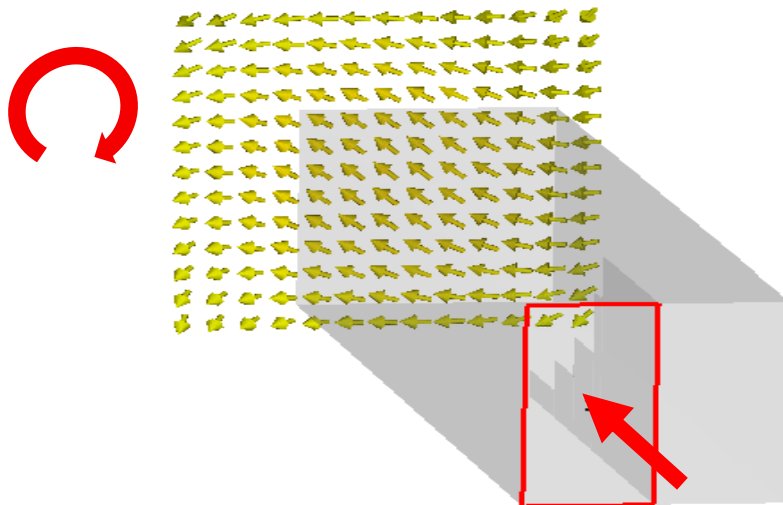
Function :

- Conversion from linear to circular polarization
- Coaxial mixing of different dual frequencies

Inducing microwave (9 GHz)

left-side input

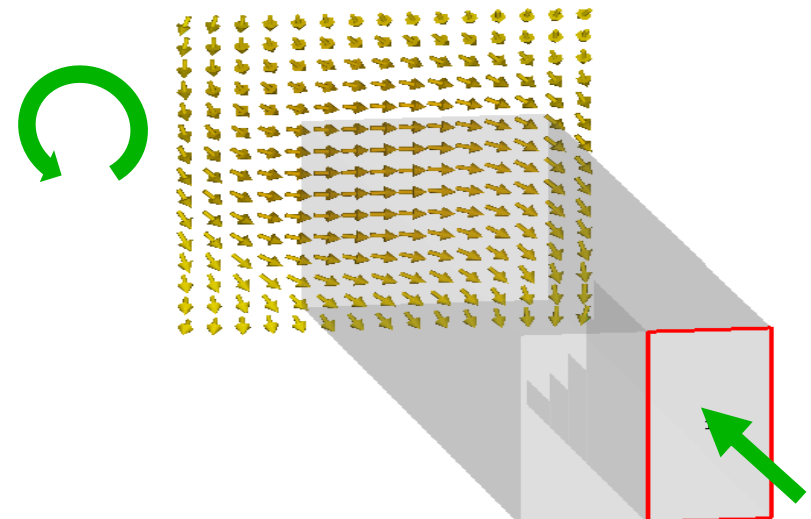
Right Hand Circular Polarization (RHCP)



Creation microwave (10 GHz)

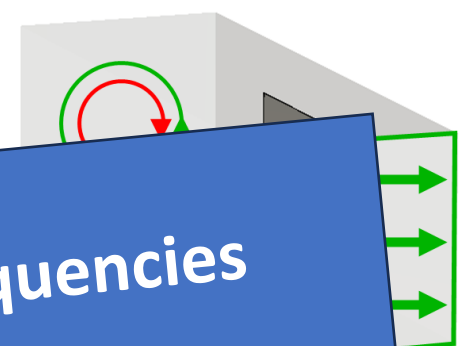
right-side input

Left Hand Circular Polarization (LHCP)



Simulation using CST studio suite's T-solver

Septum-type circularly polarized mixer



Simulation confirms that it works as a coaxial mixer of two different frequencies

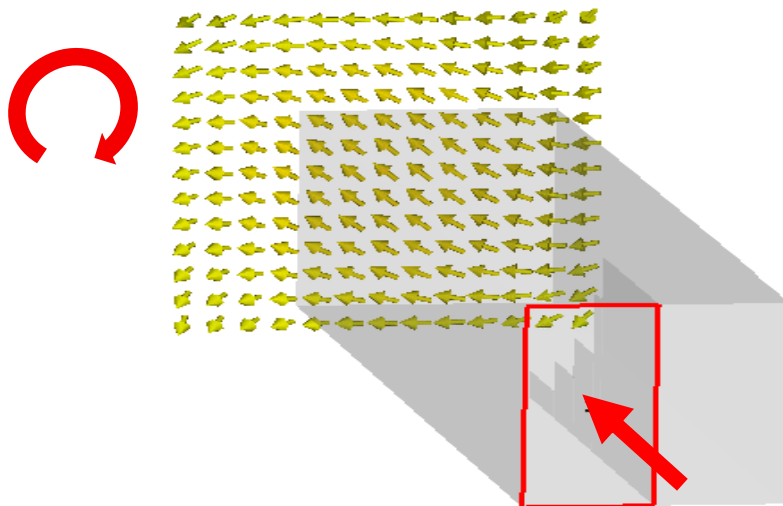
Completed optimization to X-band

Fun
• C
• C

Inducing microwave (9 GHz)

left-side input

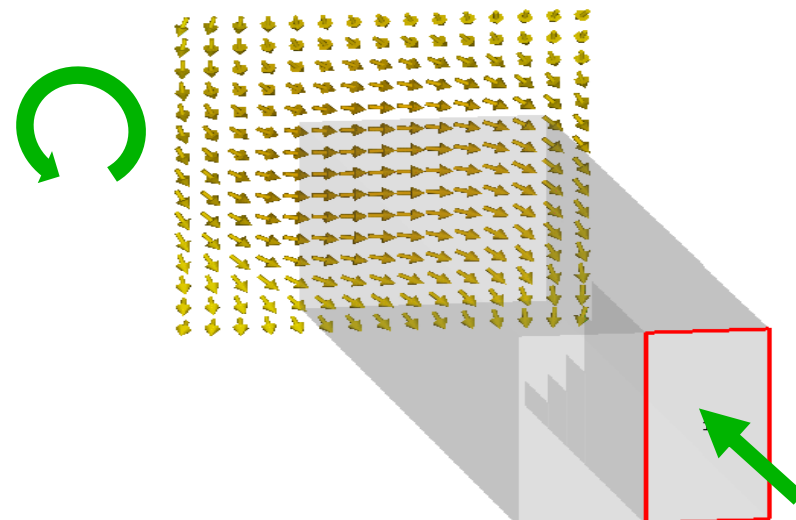
Right Hand Circular Polarization (RHCP)



Creation microwave (10 GHz)

right-side input

Left Hand Circular Polarization (LHCP)



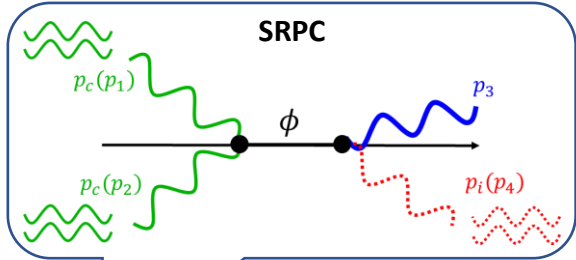
Simulation using CST studio suite's T-solver

X-band photon collider concept

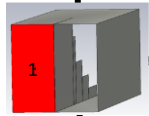
Ideal Gaussian microwave propagation focusing on free space

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GHz focus system



Circular-polarized dual-frequency mixer



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Focal point

11GHz detector

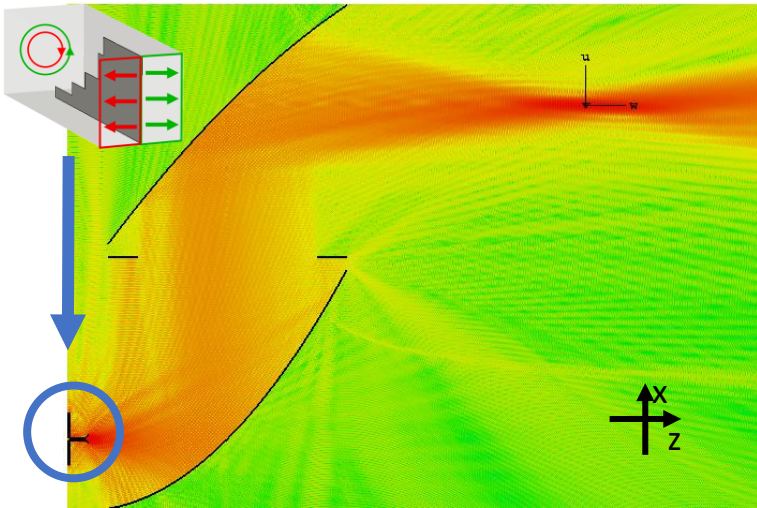
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Parabola with a hole
Horn for signal photons

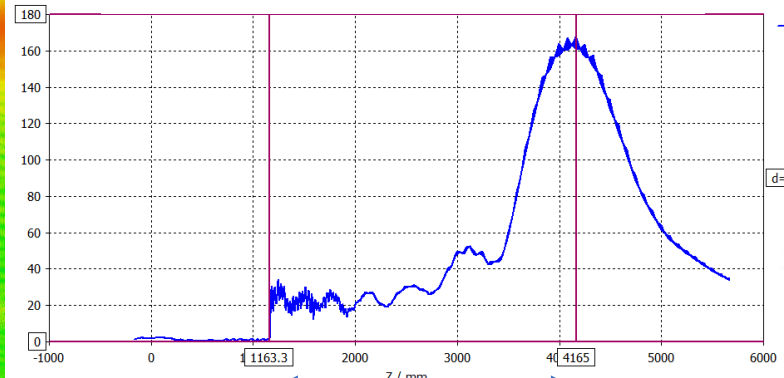
- Check performance as a mixer
- Optimization for X-band

F3m focus system + septum mixer

10 GHz x-z e-field (V/m)

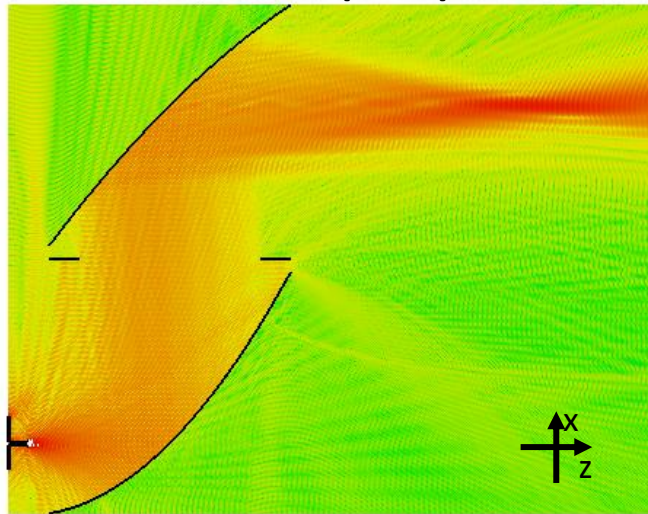


E-field along the focusing axis
Crating microwave (10 GHz)

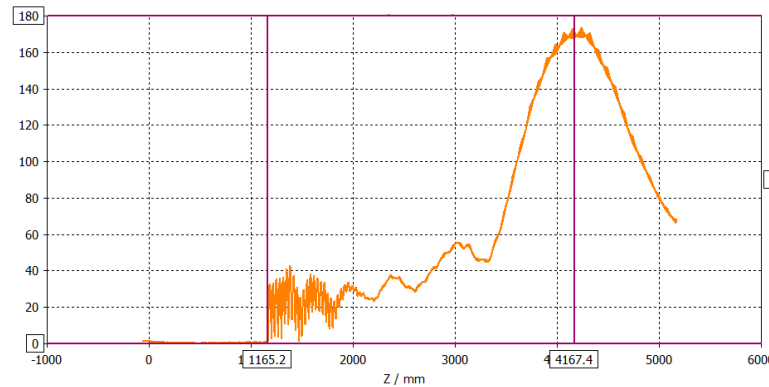


$$f = 3001.7 \text{ mm}$$

9 GHz x-z e-field (V/m)

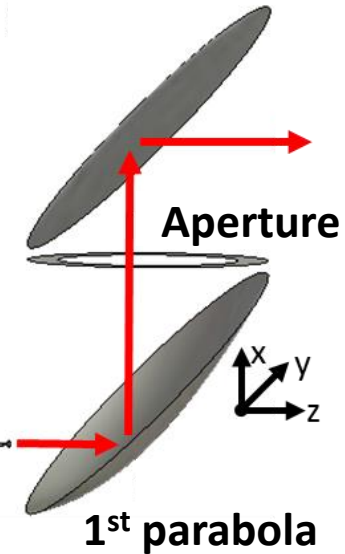


Inducing microwave (9 GHz)



$$f = 3003.4 \text{ mm}$$

2nd parabola

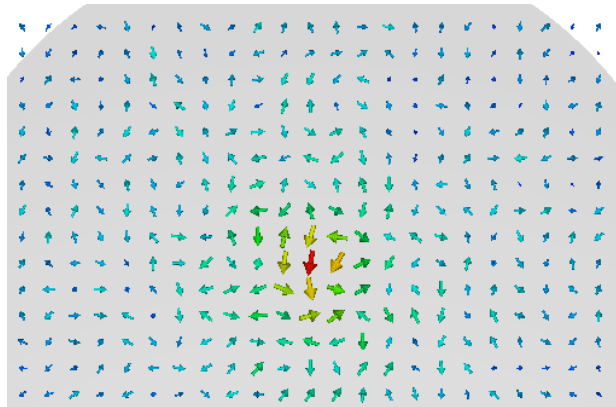


1st parabola

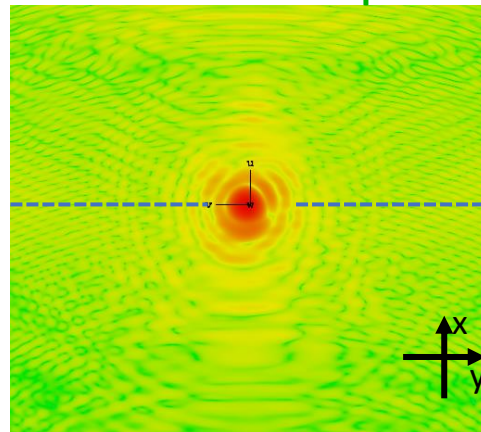
Focusing at designed focal length at 9 GHz and 10GHz

Focal point beam profile

$$f(x) = A \exp\left(\frac{-2x^2}{\sigma^2}\right)$$



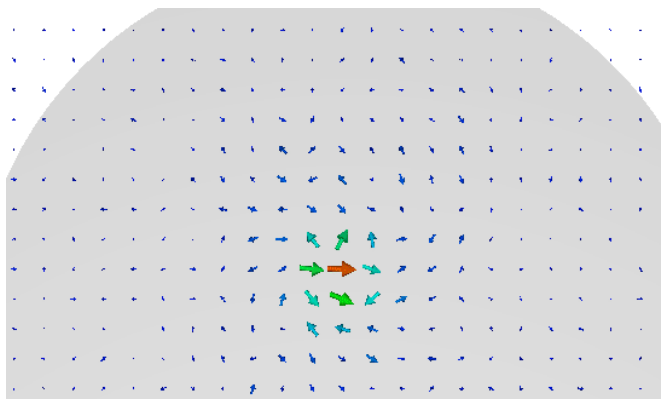
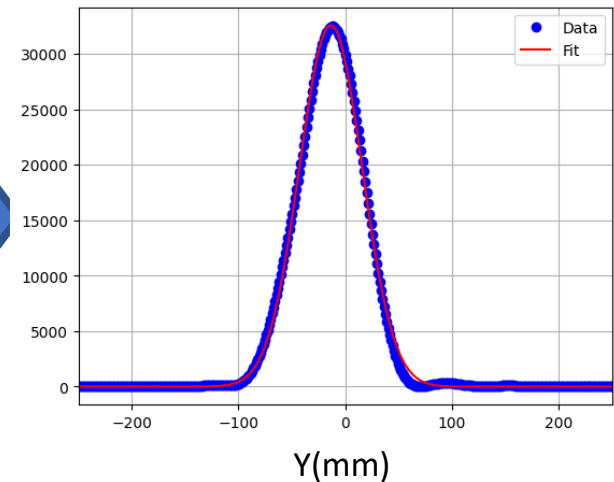
Creation microwave (10 GHz)
X-Y e-field at focal point



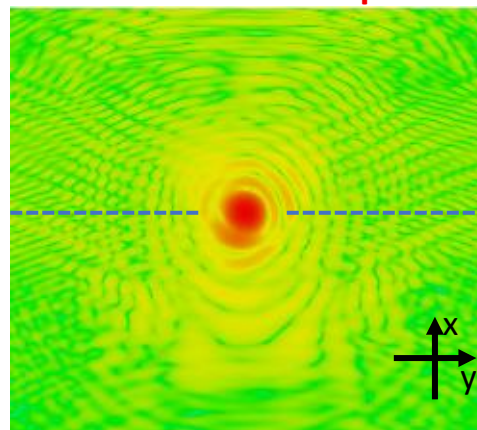
$(V/m)^2$



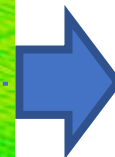
Gaussian fitting on Y-axis



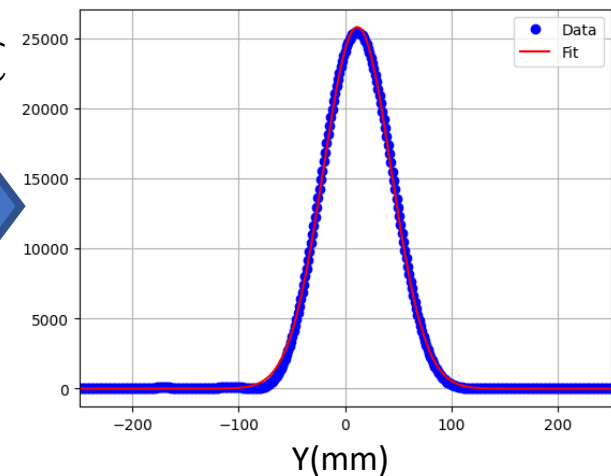
Inducing microwave (9 GHz)
X-Y e-field at focal point



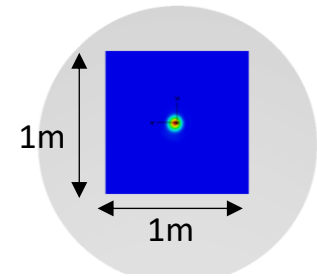
$(V/m)^2$



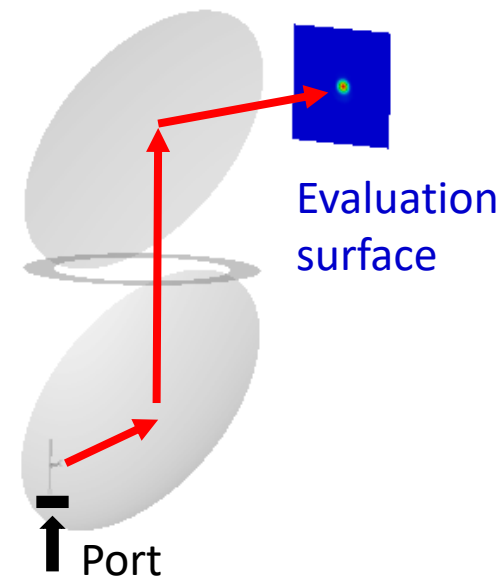
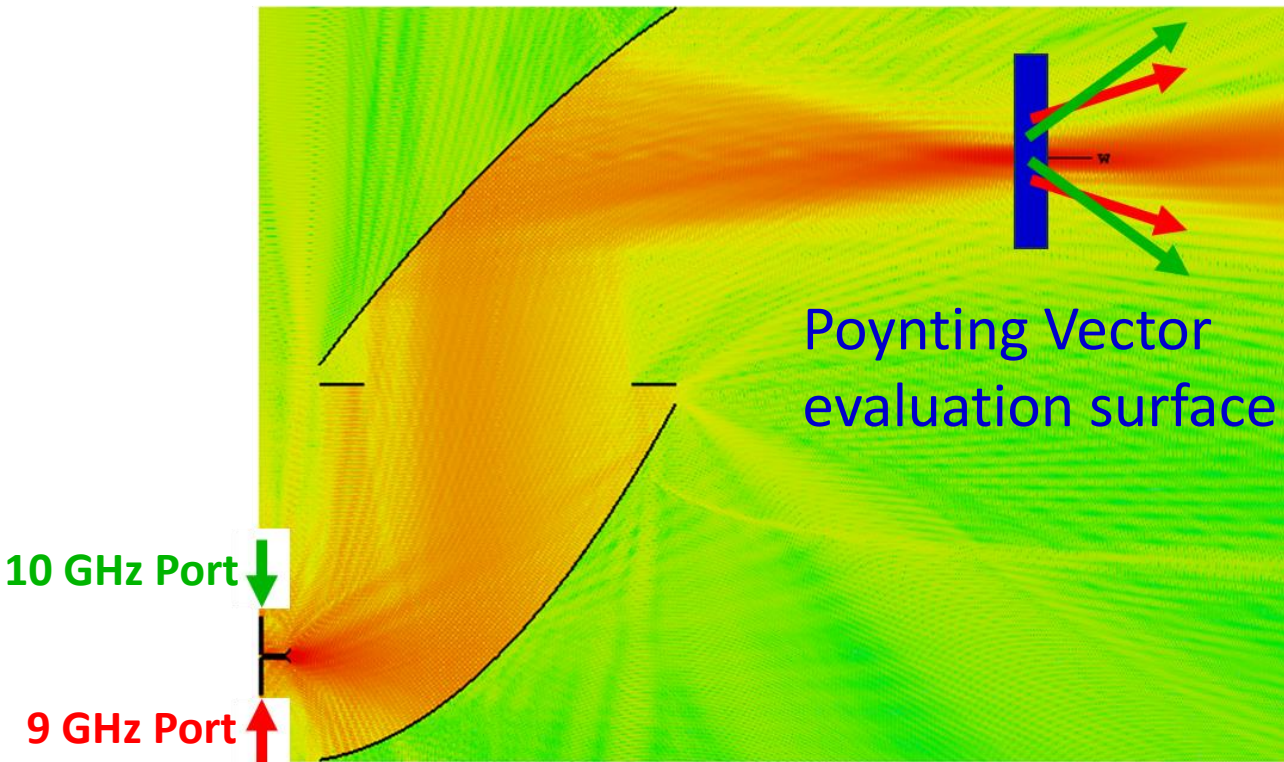
Gaussian fitting on Y-axis



Propagation efficiency to the focal point



Evaluate the microwave propagation efficiency between Port and the focal point.



10 GHz : 84.8 % photons pass through the evaluation surface

9 GHz : 80.6 % photons

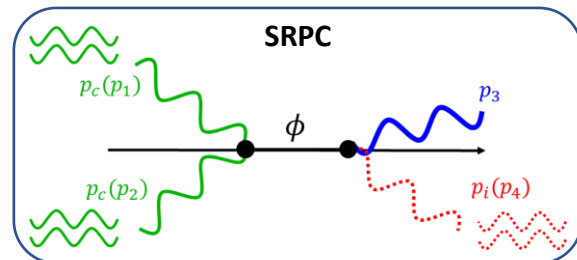
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X-band photon collider concept

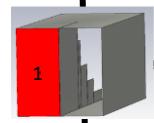
More than 80% of input photons reach the focal point

9 GHz
Inducing microwave pulse

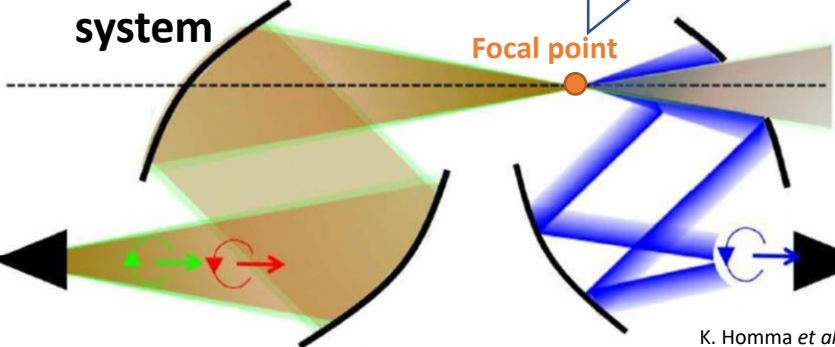
GHz focus system



Circular-polarized dual-frequency mixer



Creation microwave pulse
10 GHz



11GHz detector

K. Homma et al., JHEP, 9(2020) 095

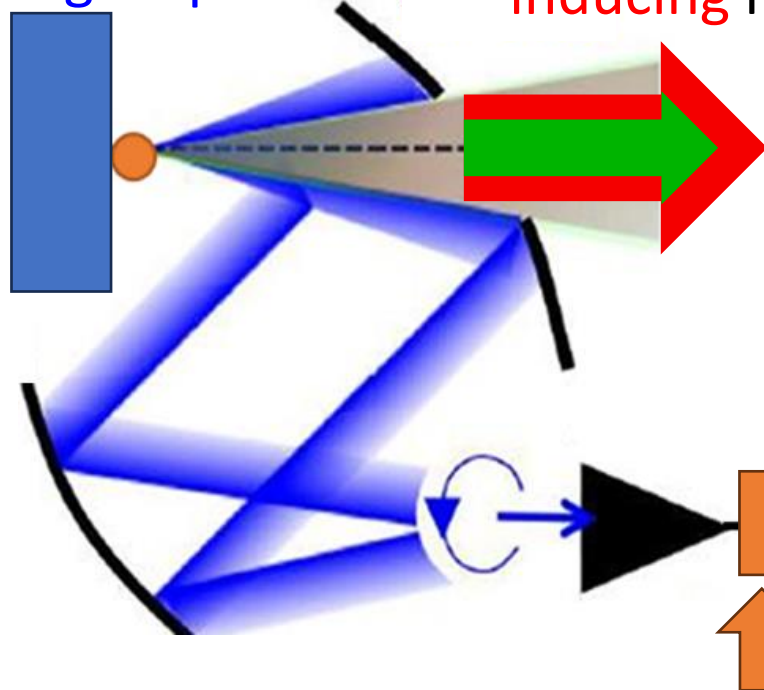
Parabola with a hole
Horn for signal photons

- Check performance as a mixer
- Optimization for X-band

Selective collection of large angle scattered signal photon

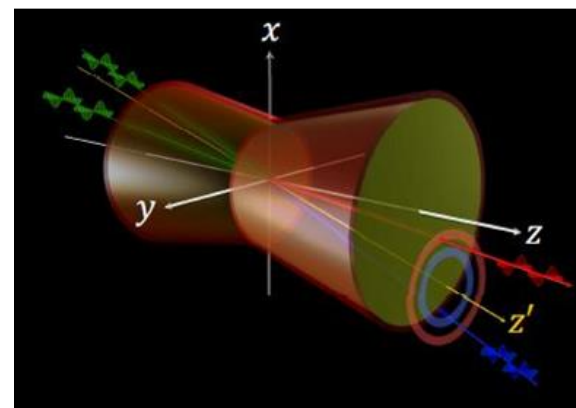
Parabola with a hole for selective **signal light** acquisition

Large angle scattering
imitate signal photon



Most of the
creation and
inducing microwave

Asymmetric collision



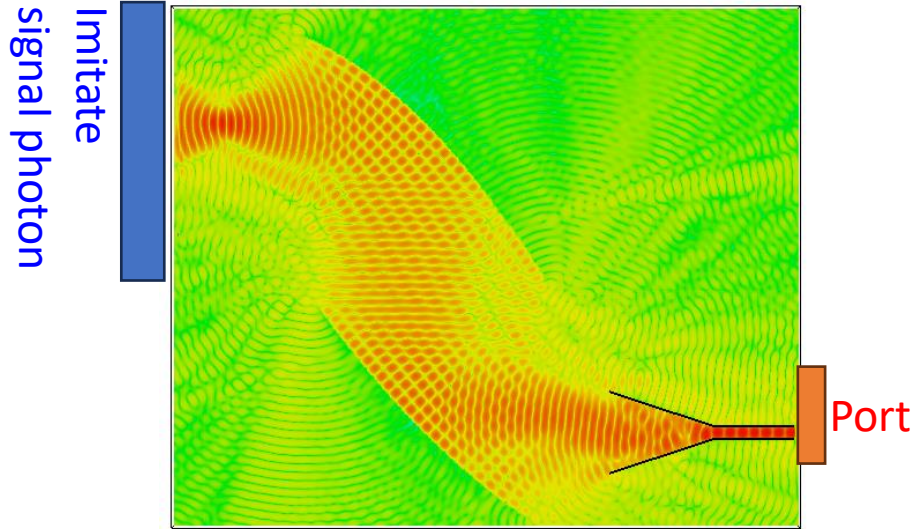
Amplifier

Detector

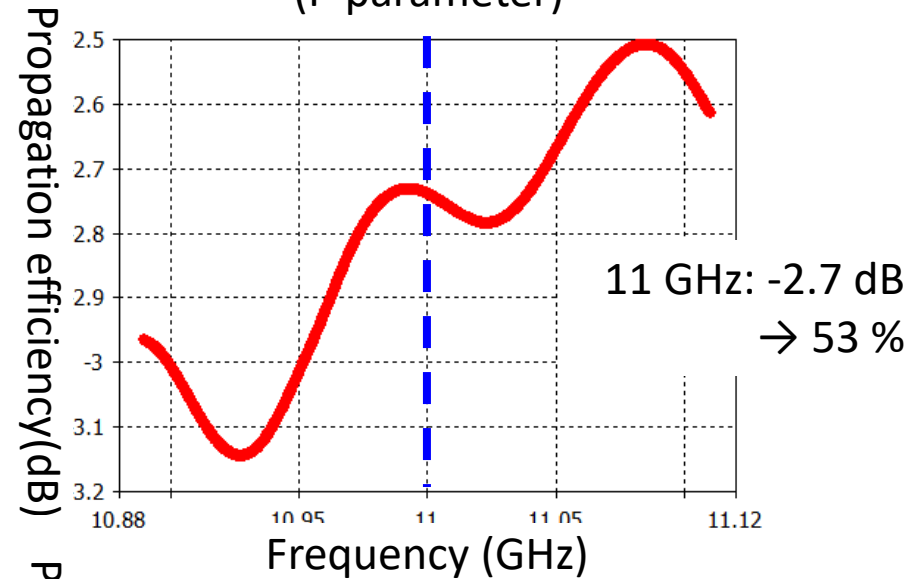
Simulation of signal power transmission
from **imitate signal photon** to **horn's output port**

Signal light propagation efficiency

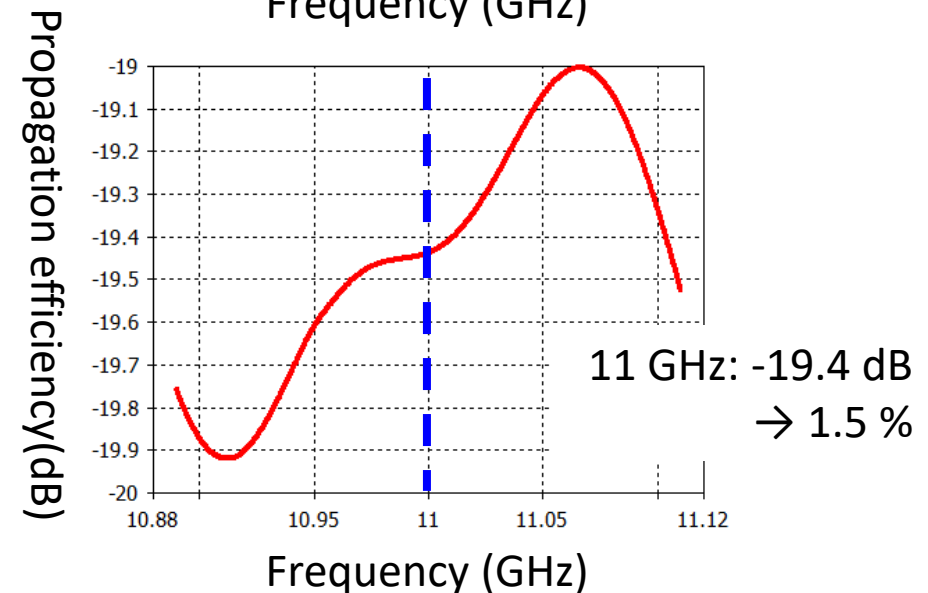
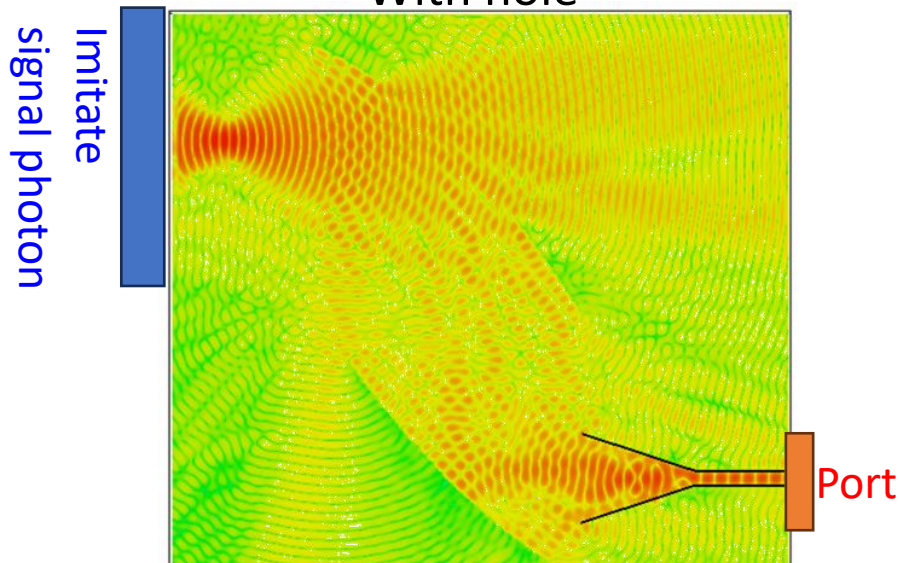
No hole



Propagation efficiency
(F-parameter)

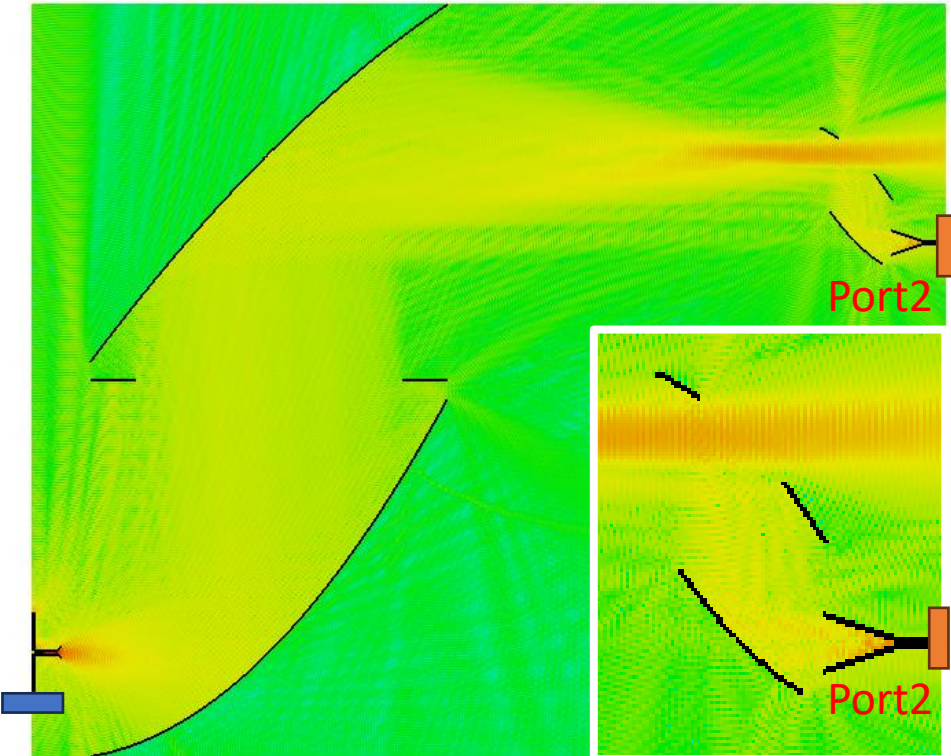


With hole



Intensity of **creation** and **inducing** light remaining to the signal light horn

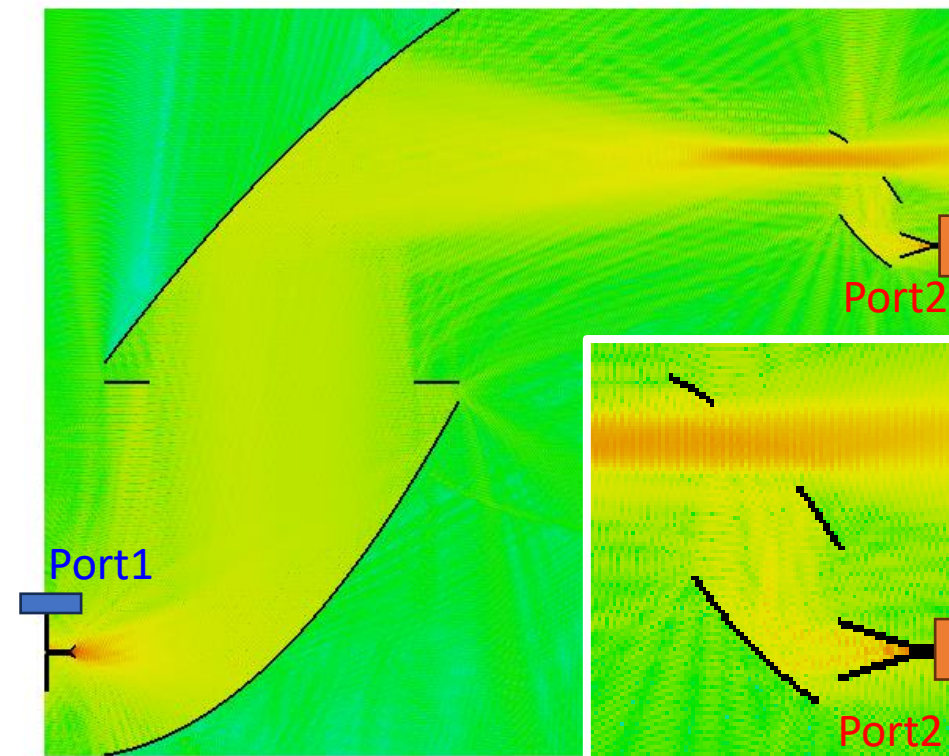
Creation microwave (10 GHz)



$$S_{2,1} = -68.9 \text{ dB}$$

$$\rightarrow 1.3 \times 10^{-5} \%$$

Inducing microwave (9 GHz)



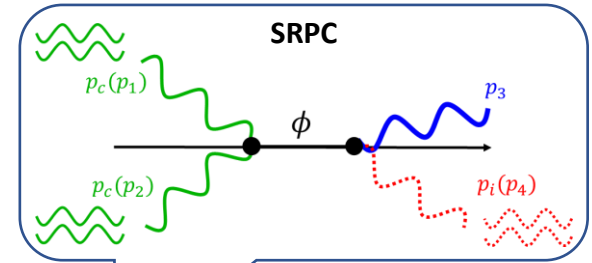
$$S_{2,1} = -60.8 \text{ dB}$$

$$\rightarrow 8.3 \times 10^{-5} \%$$

Selective exclusion of **creation** and **inducing** light archived by parabola with a hole

X-band photon collider concept

More than 80% of input photons reach the focal point



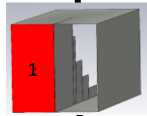
9 GHz
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GHz focus system

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11GHz detector

Circular-polarized dual-frequency mixer



Creation microwave pulse
10 GHz

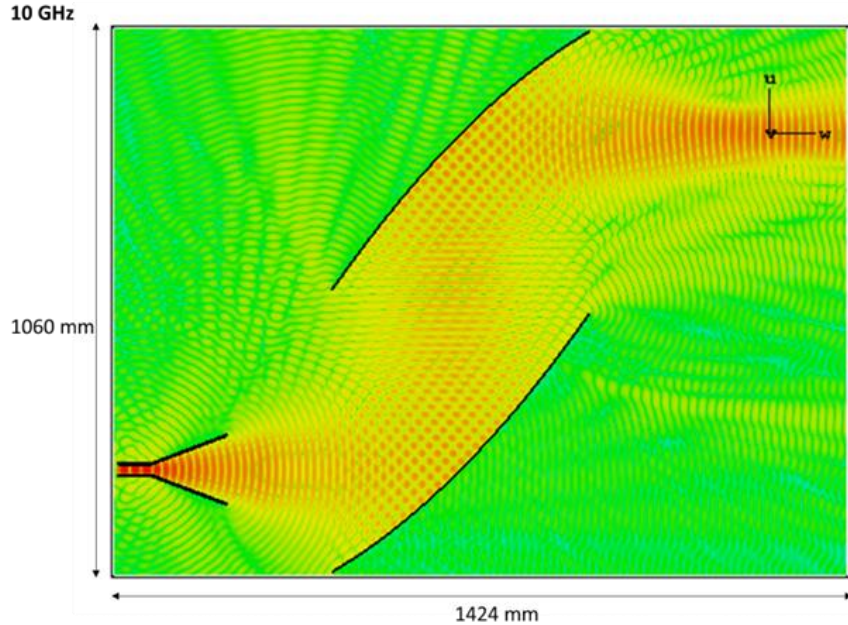
Parabola with a hole
Horn for signal photons

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- Check performance as a mixer
- Optimization for X-band

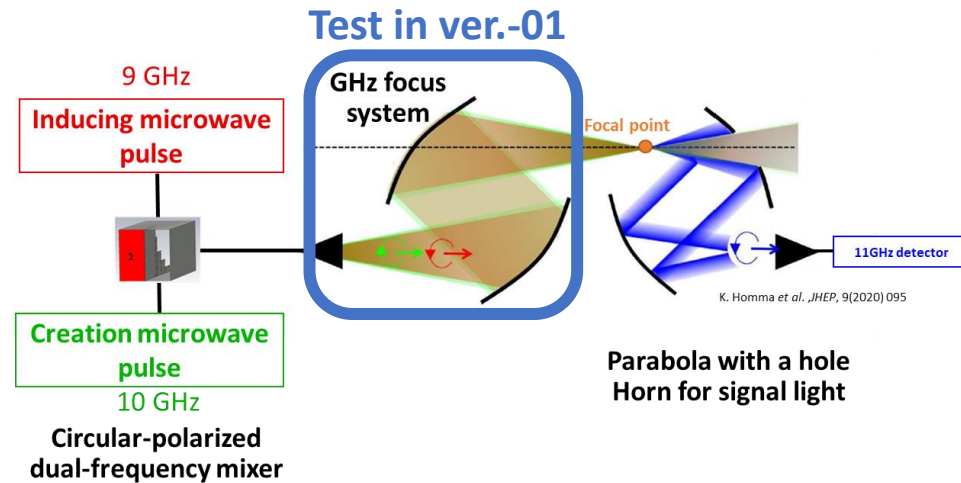
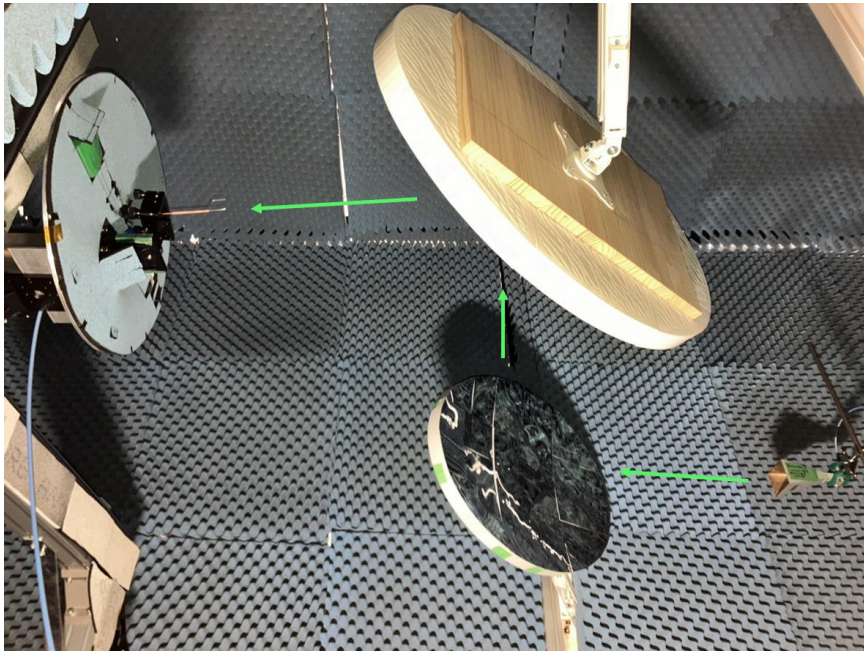
Signal photon and creation/inducing microwave beam can be separated

Ver.-01



Purpose :
Construction and verification of compact X-band focusing system

→ Details are on the poster



Summary

| Ver. | outline |
|------|--|
| pre | Comprehensive design of the entire focusing system through simulation |
| -01 | Verification the X-band focusing system <ul style="list-style-type: none"> • Quick, flexible, inexpensive, and simple ways to fabricate parabolas • Focusing system alignment methods • Methods for measuring focal point profiles |
| 00 | Install Septum polarizer, Parabola with a hole, Signal amplifier system Pre-pilot search |

now
←

Step-by-step upgrade

- more powerful photon source
- lower noise environment