

# Electromagnetic Deactivation of the Human Coronavirus through Resonance Phenomena

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## Queen's University:

- Established in 1841
- Member of Canadian U15
- Students:
  - 5,700 post-graduate
  - 26,000 undergraduate

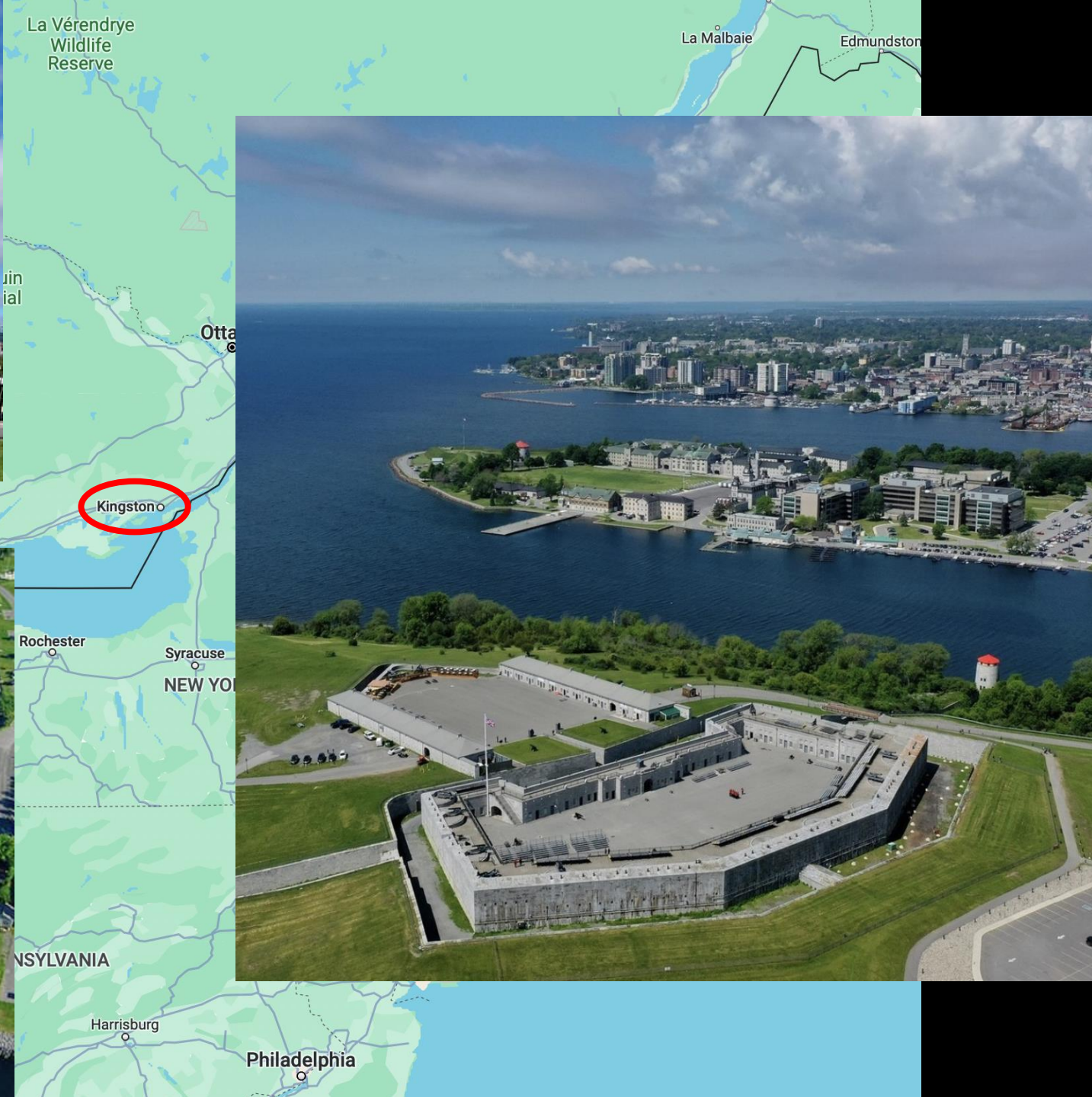
## Electrical and Computer Engineering:

- 49 faculty (incl. 11 cross-appointed)
- 200+ Masters/PhD students
- largest Engineering Department



**SMITH**  
**ENGINEERING**  
Queen's University

Stephen J. R. Smith (Electrical Engineering, '72)  
makes historic gift of \$100M to the Faculty of  
Engineering at Queen's University



MICHIGAN

Kingston

Rochester

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NEW YORK

PENNSYLVANIA

Harrisburg

Philadelphia

# Outline

- Background
  - Structure resonant energy transfer (SRET)
- System Design
- Virological Study
- Findings
- Conclusion

# Team



Dr. Ian Goode, Postdoc  
Electrical Engineering



H. Banting, PhD candidate  
Electrical Engineering



C. Gallardo, PhD candidate  
Faculty of Health Sciences



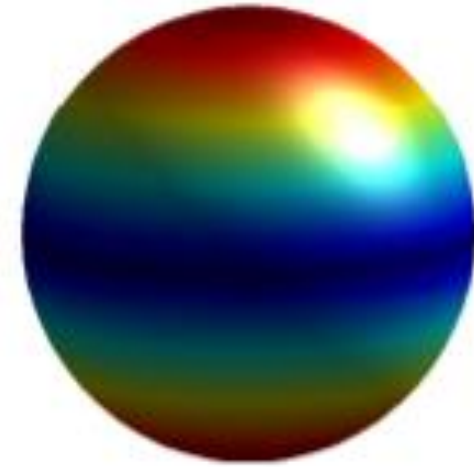
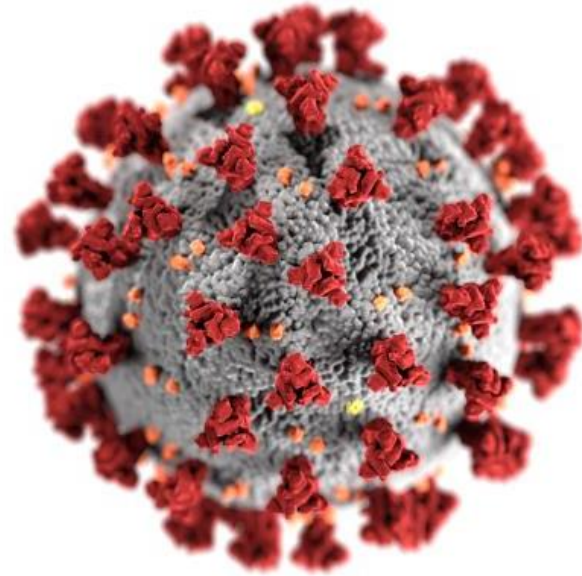
Prof. C. Colpitts  
Faculty of Health Sciences



Prof. C. Saavedra  
Electrical Engineering

# Background

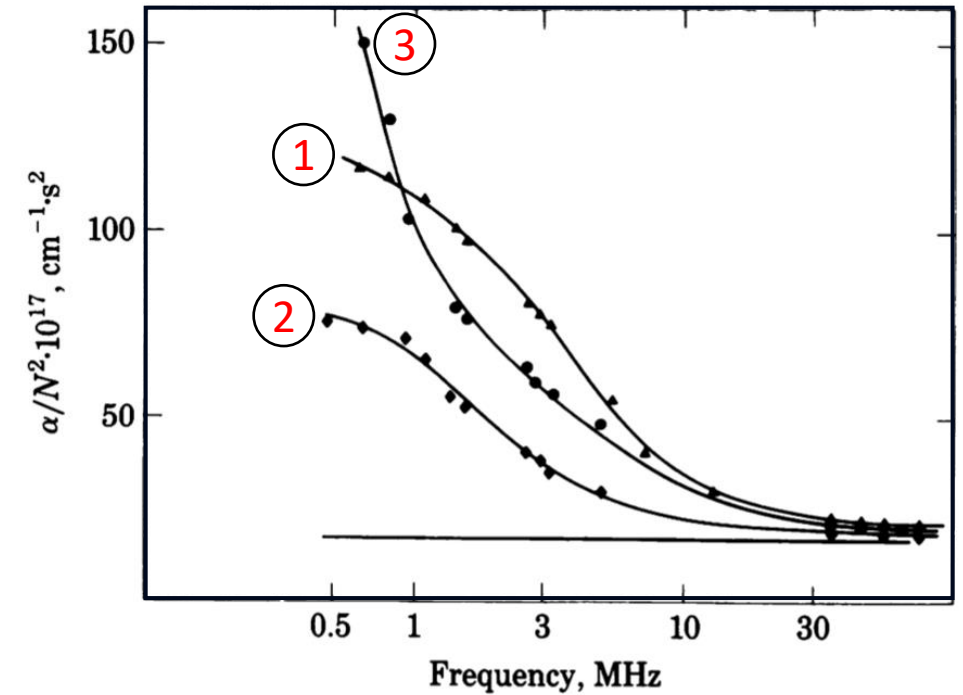
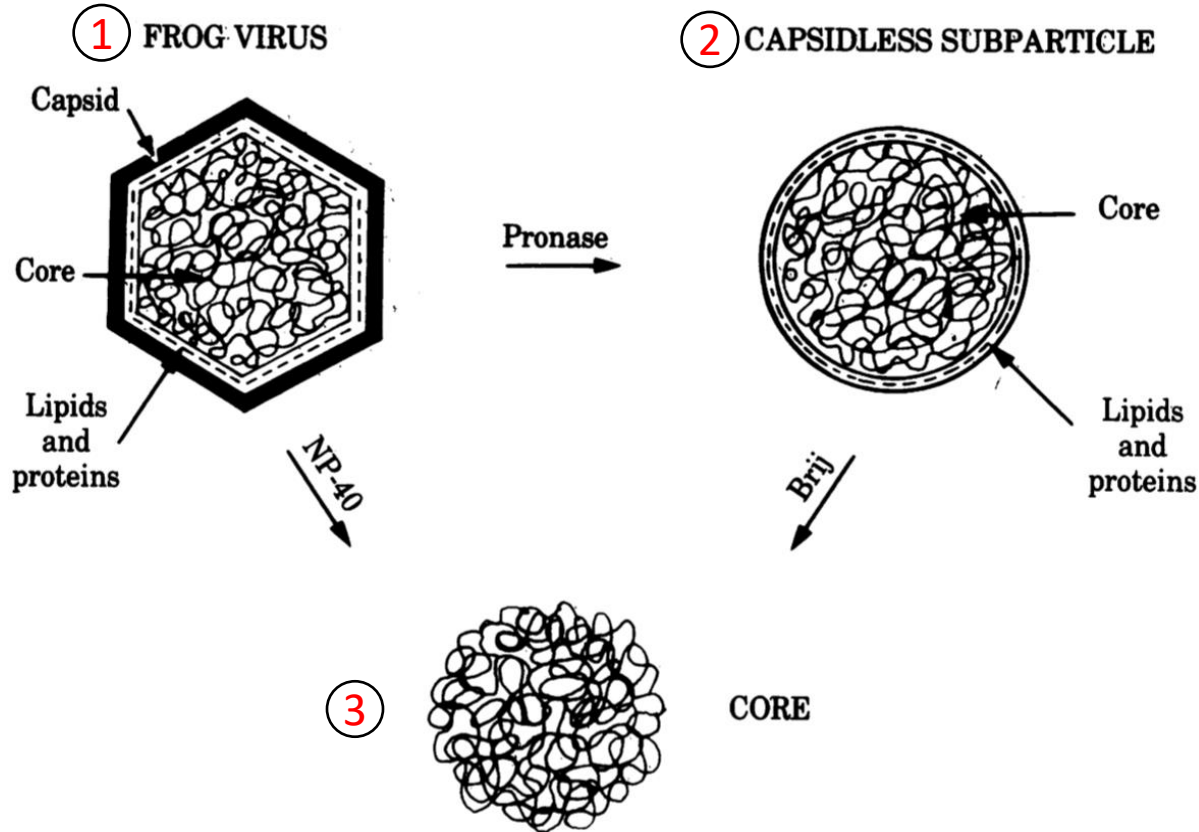
# Structure Resonant Energy Transfer (SRET)



- For viruses with diameters in the 100 nm range, significant energy absorption is observed in the microwave bands
- Virus envelope experiences acoustic vibrations and eventually ruptures through mechanical stress, **not** through microwave heating
- Viruses with spherical symmetry are better candidates for SRET deactivation than viruses with tubular geometries



# Early studies



Y Robach et al, "Ultrasonic absorption evidence for structural fluctuations in frog virus 3 and its subparticles", *Proceedings of the National Academy of Sciences*, 80(13), 3981-3985, 1983

➔ Babinová, M., Sourivong, P. & Babinec, P. Resonant absorption of ultrasound energy as a method of HIV destruction. *Med. Hypotheses*, 55, 450, 2000

## Recent studies

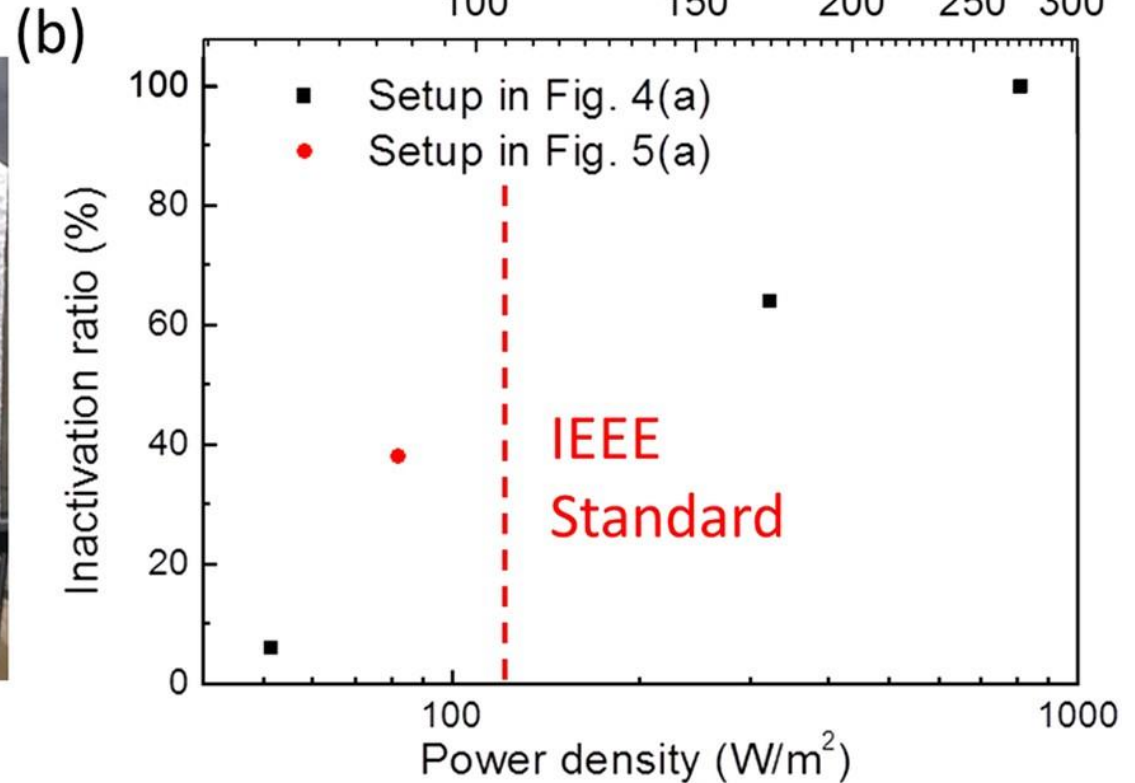
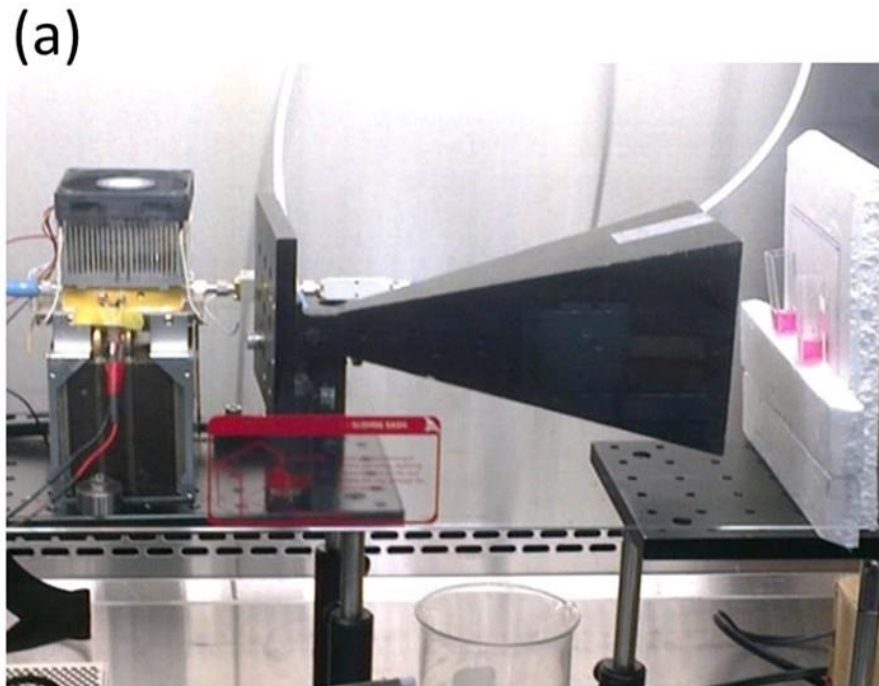
Virus	Diameter (in nm)	Resonant Frequency (in GHz) $f = \frac{2400}{2D}$
Influenza A	93 ± 5 (H D) [15]	12.9 ± 0.7
	100 (EM D) [26]	12
EV71	35 ± 2 (H D) [15]	34 ± 2
	28.5 ± 1.5 (EM D) [23]	42 ± 2
SARS-CoV-2	60–140 (EM D complete range) [25]	8.5–20
	70–80 (EM D average size) [26]	15–17

H D and EM D indicate hydrodynamic and electron microscope diameters respectively.

Barbora, A. & Minnes, R. Targeted antiviral treatment using non-ionizing radiation therapy for SARS-CoV-2 and viral pandemics preparedness: Technique, methods and practical notes for clinical application. **PLoS ONE** 16, e0251780 (2021).

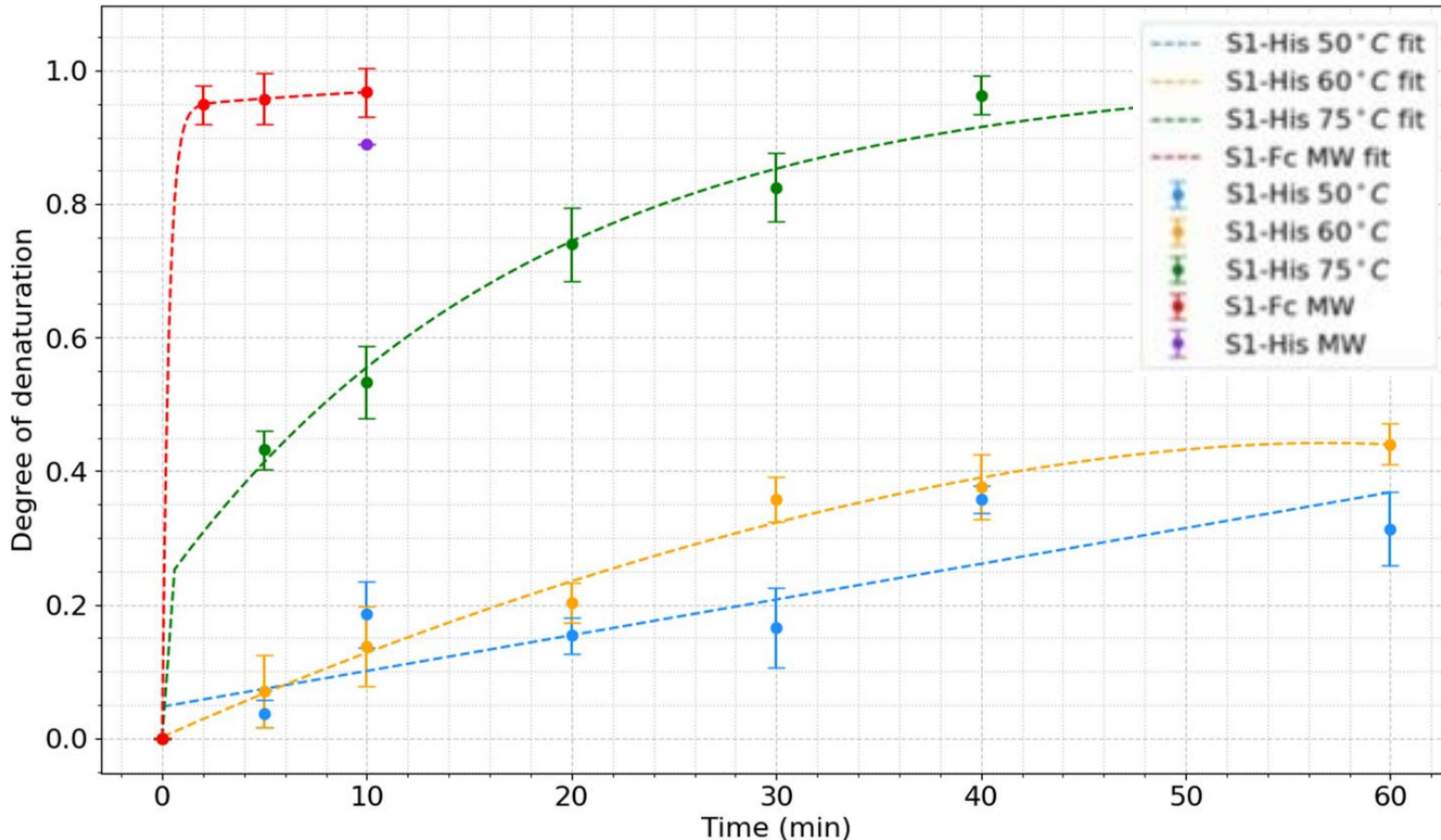
[25] Scheller C, Krebs F, Minkner R, Astner I, Gil-Moles M, Wätzig H. Physicochemical properties of SARS-CoV-2 for drug targeting, virus inactivation and attenuation, vaccine formulation and quality control. **Electrophoresis**. 2020;41(13-14):1137-1151.

# SRET study with Influenza A



RF power = 6.3 W (antenna input)

# Denaturation of virus spike protein

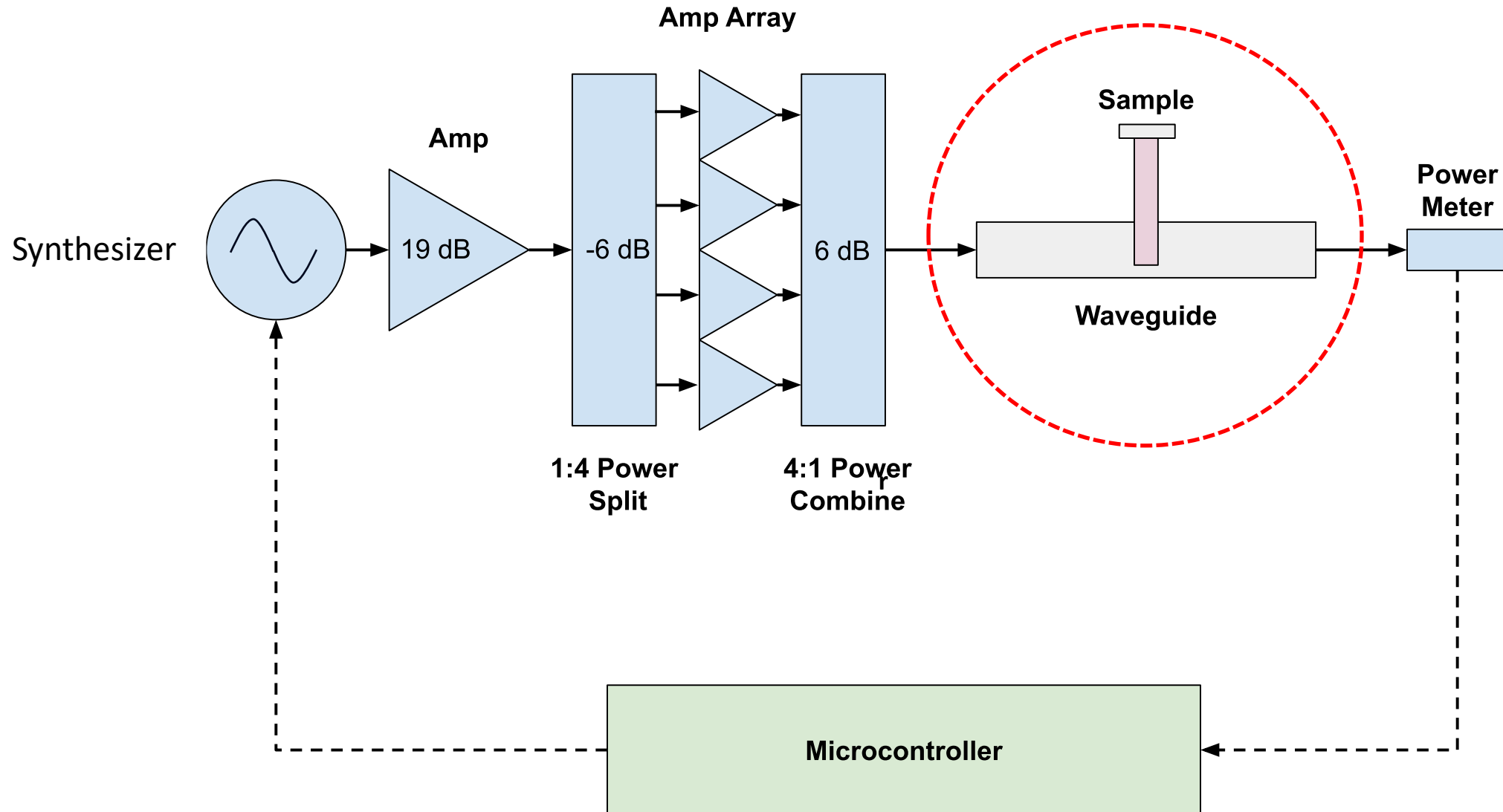


- microwave power = 700 W
- frequency = 2.45 GHz
- Exposure = 2 minutes to denature the protein to around 95%.

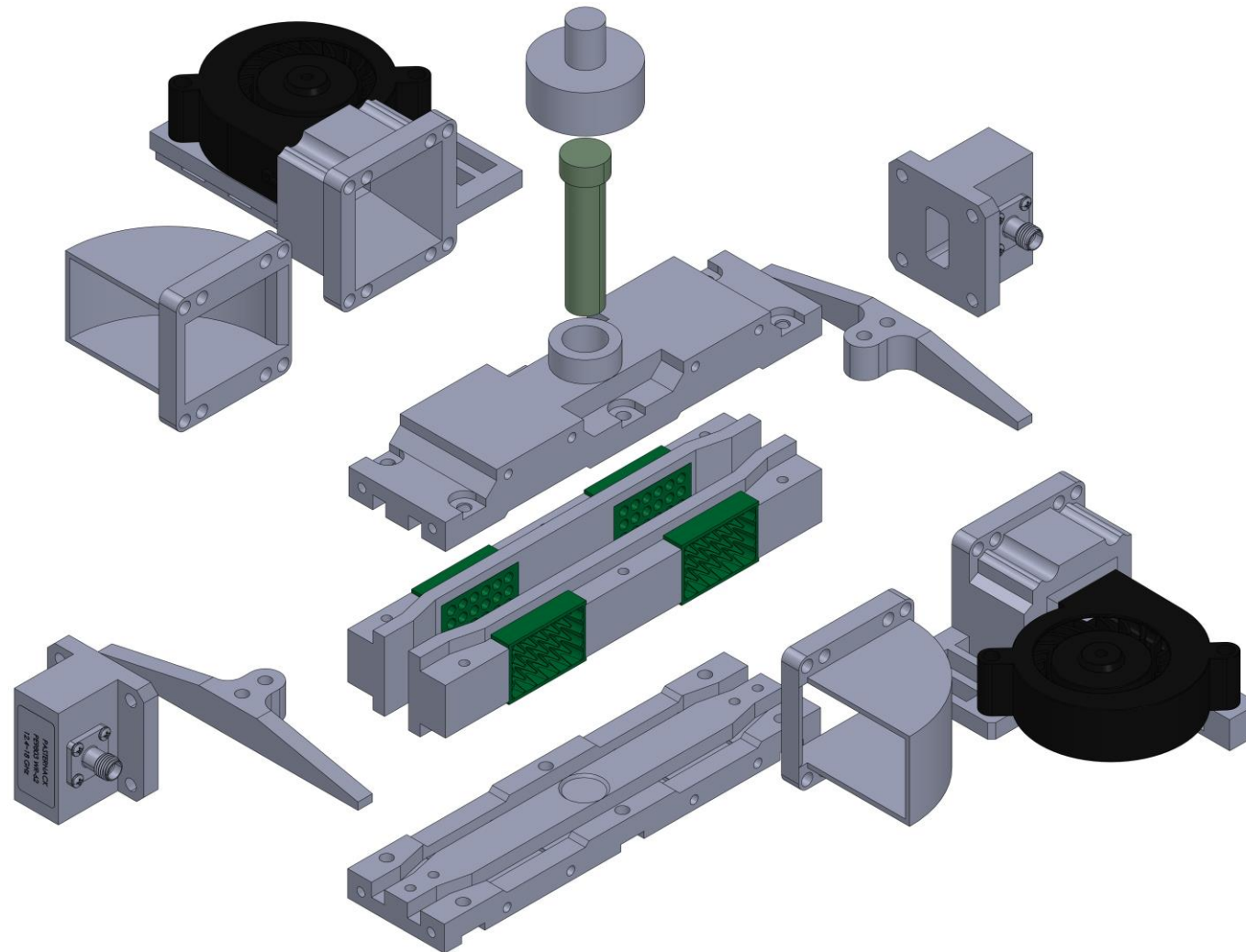
Afaghi, P., Lapolla, M.A. & Ghandi, K. Denaturation of the SARS-CoV-2 spike protein under non-thermal microwave radiation. *Scientific Reports*, 11, 23373 (2021)

# System Design

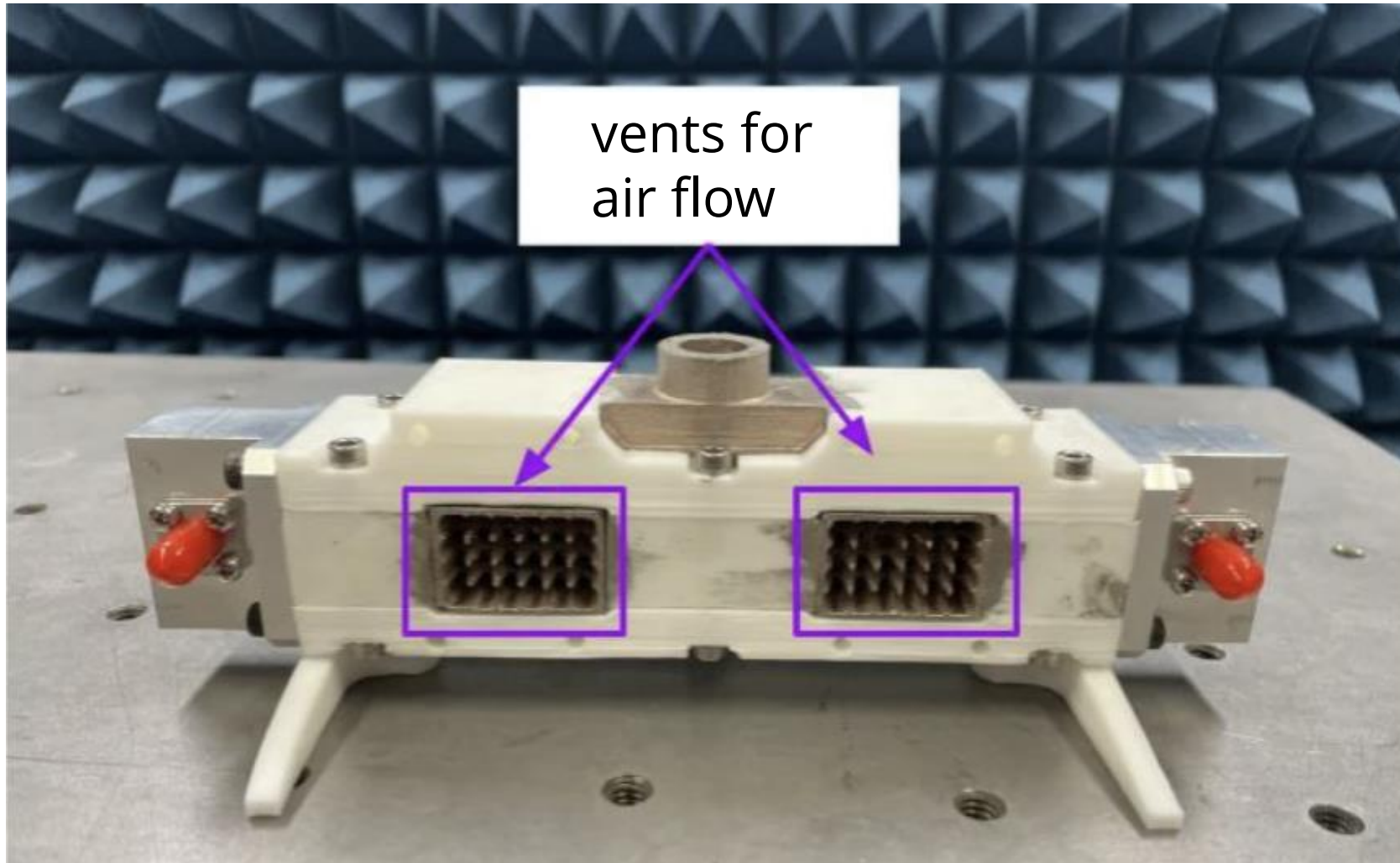
# General approach



# Air-Cooled System

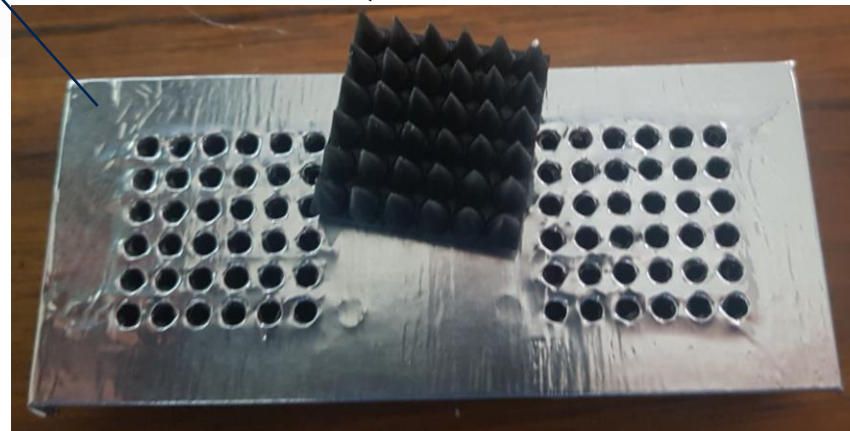
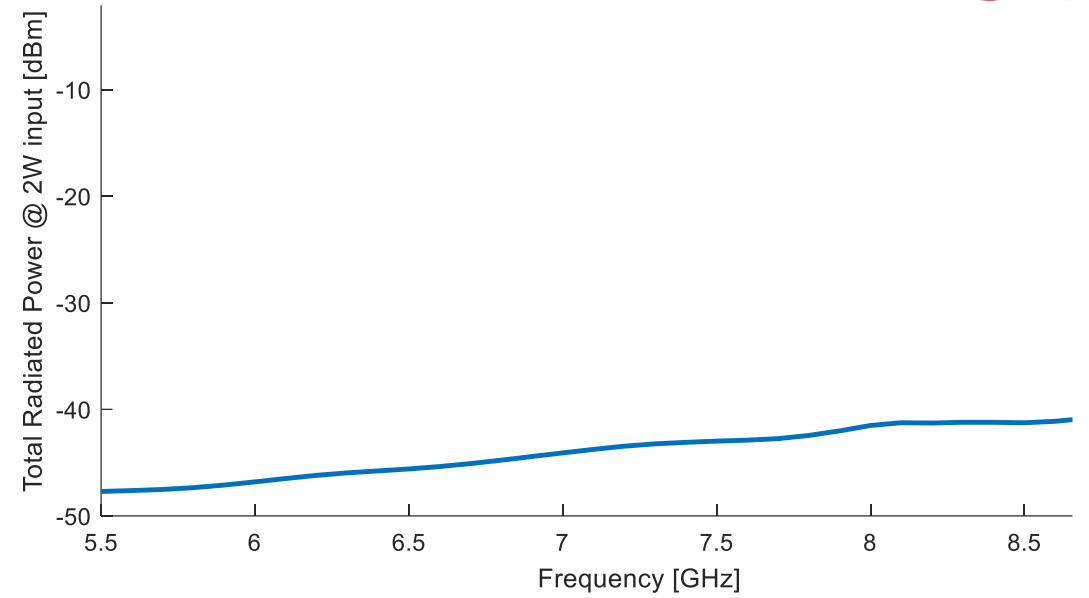
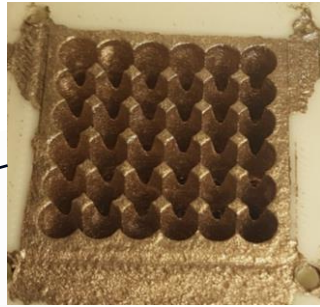
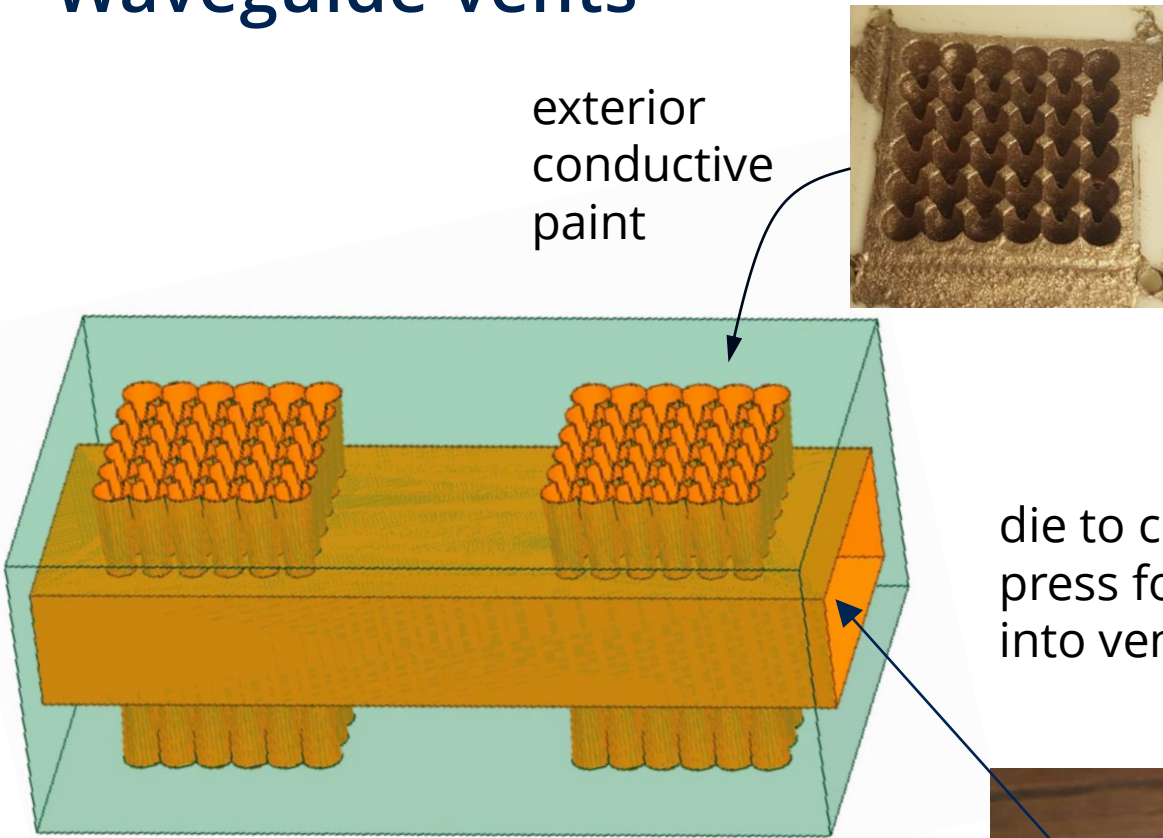


## Assembled air-cooled waveguide (without fans)

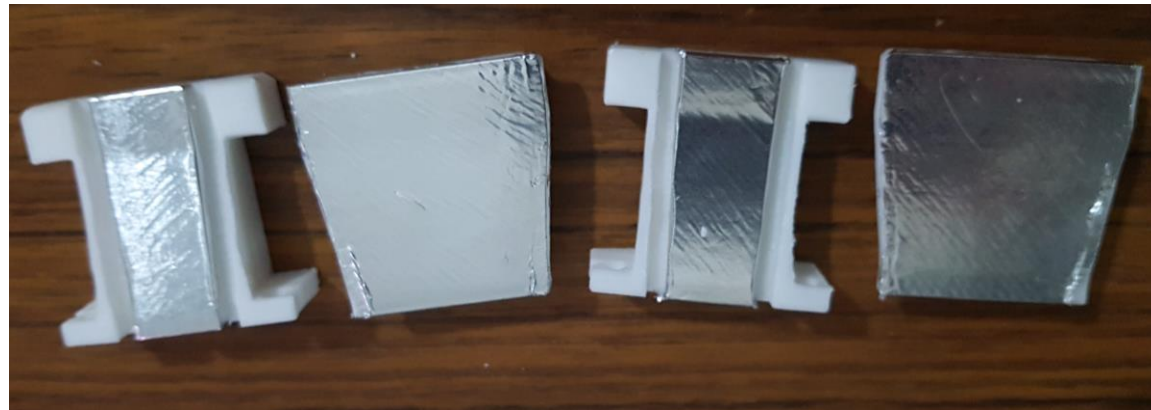
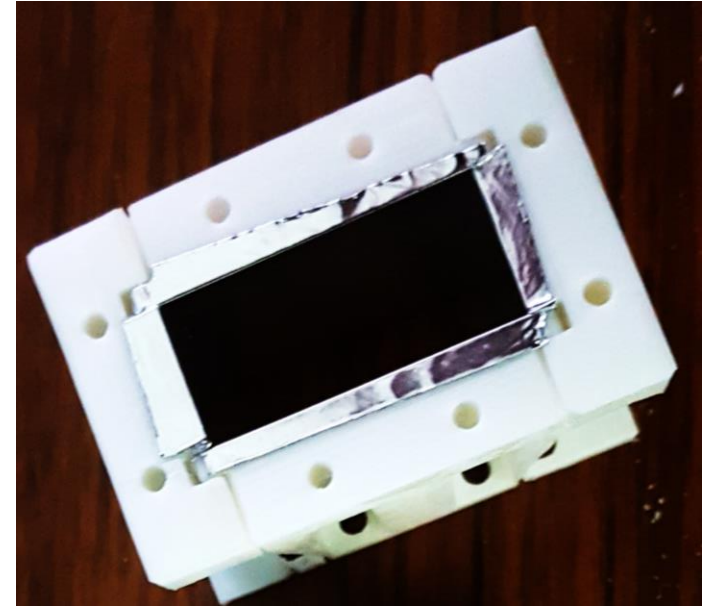
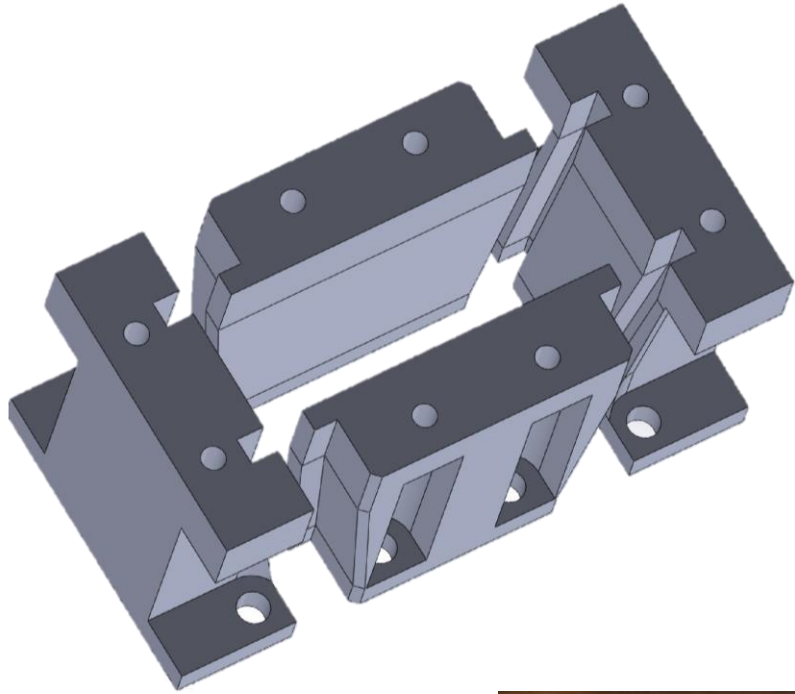




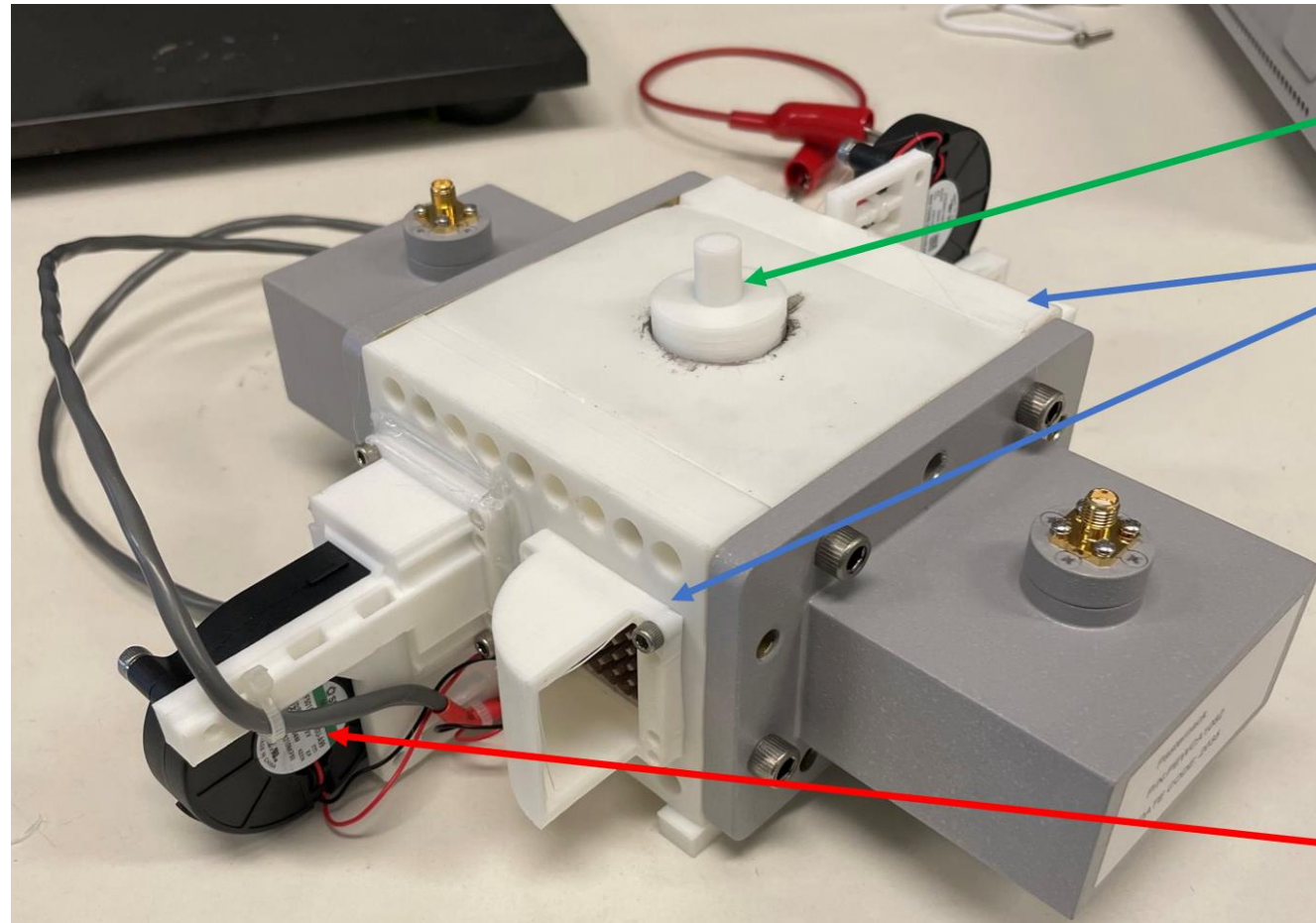
# Waveguide vents



# Waveguide assembly



# WR284

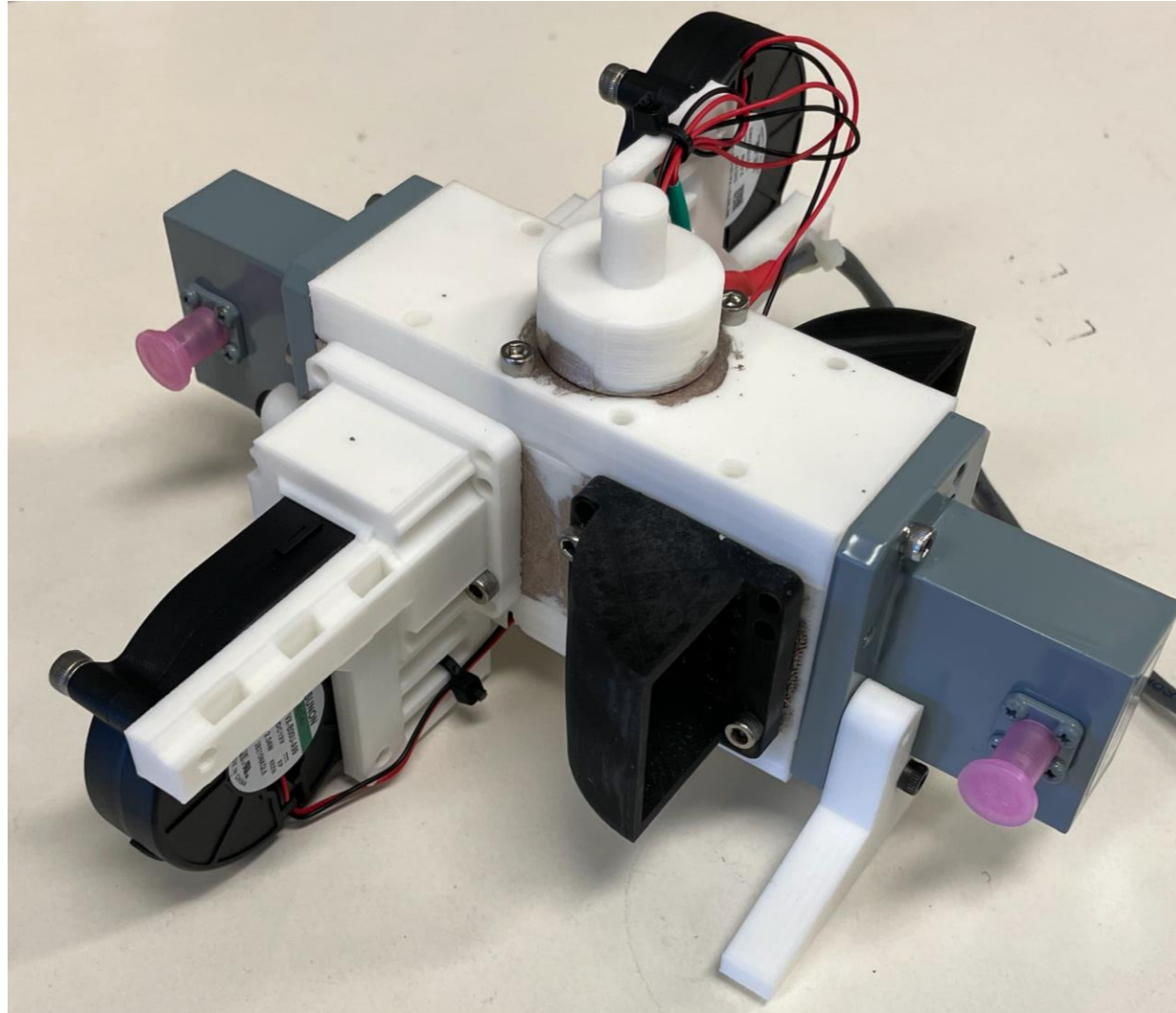


Sample slot

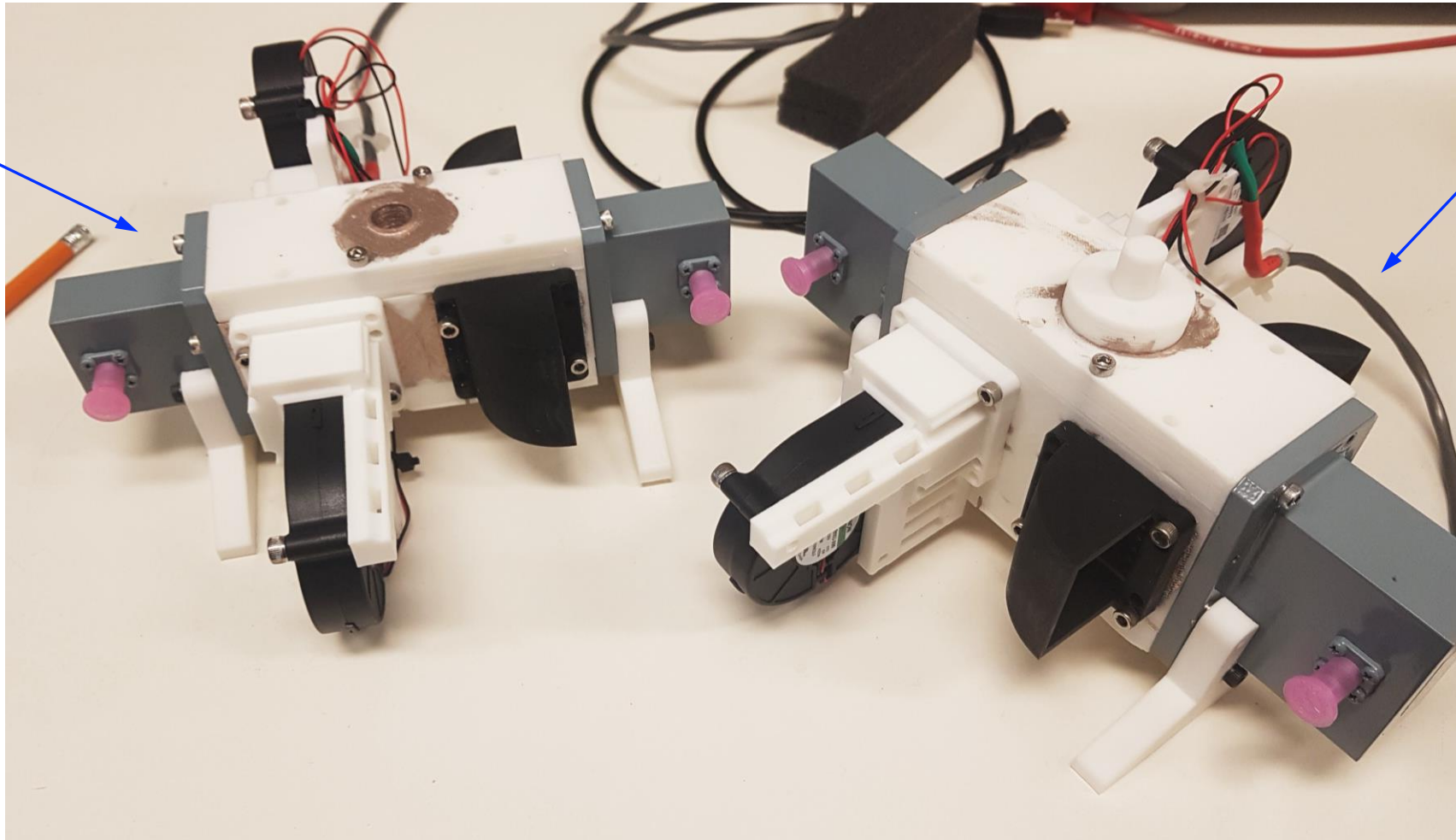
Exhaust ducts

Intake fans

# WR-62 system



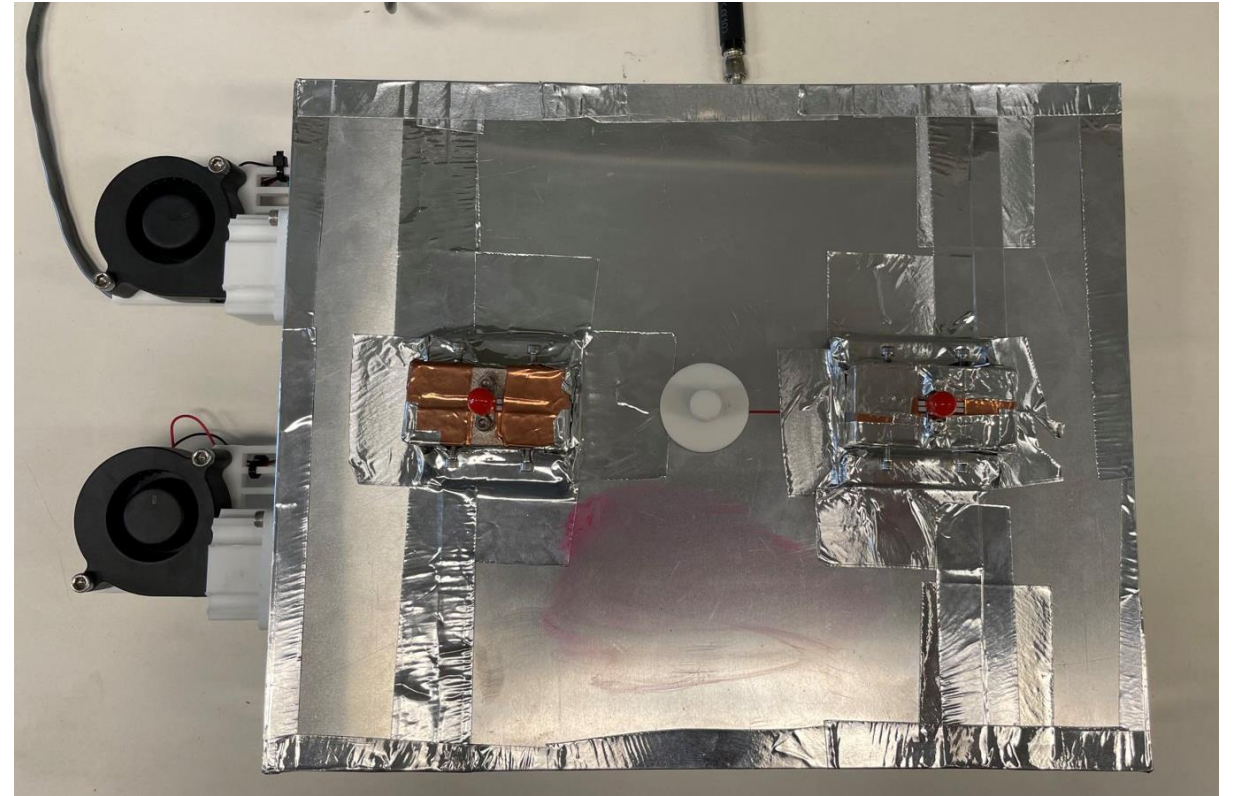
WR 137



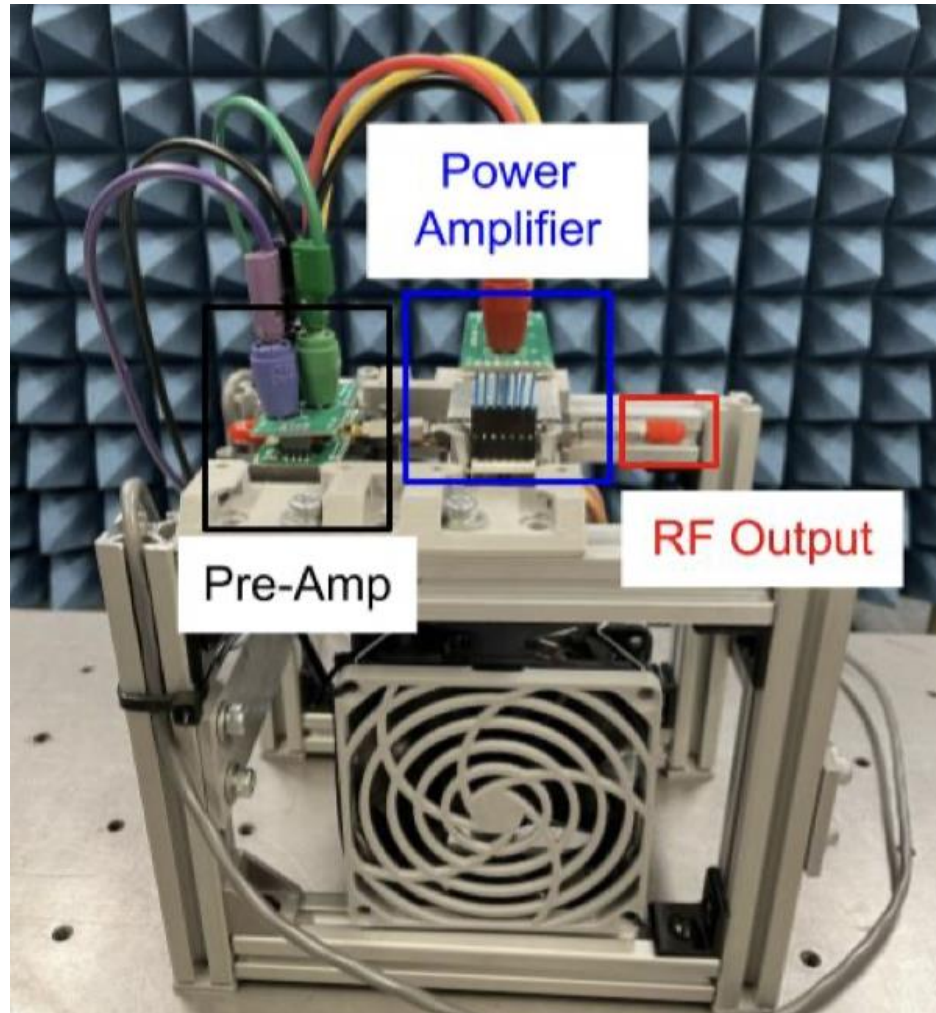
WR 187

- Solution heats **18-29°C** over 7.5 min cycle **without** cooling
- Solution heats **5-9°C** over 7.5 min cycle **with** cooling

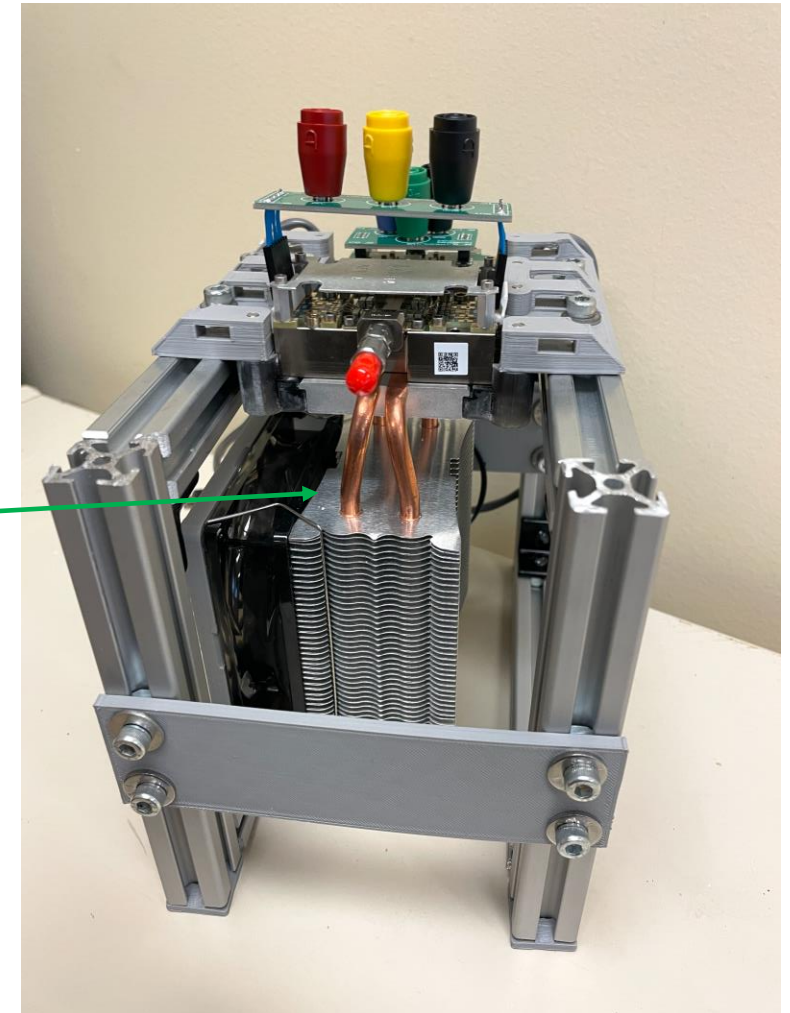
# 800 MHz to 1800 MHz



# Power Amplifier



liquid cooling



# Virological study



## Virus

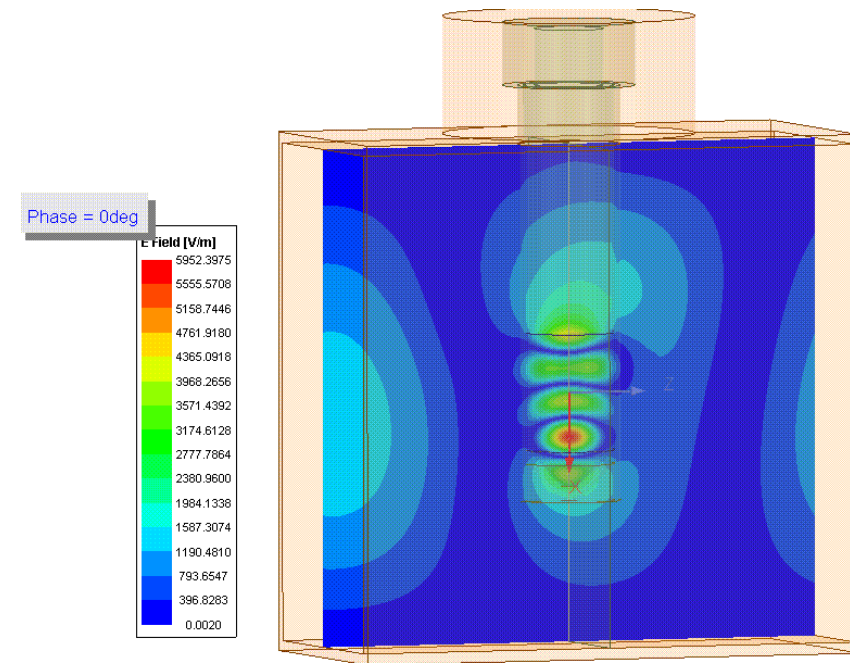
- **HCoV-229E** virus obtained from the US Biodefense and Emerging Infections (BEI) Research Resources Repository (NR-52726).
- 1 mL aliquots (samples) of HCoV-229E diluted to  **$1 \times 10^6$  PFU/mL** were used for each experiment. PFU = plaque forming unit

## Host cells

- **Huh7** cells (JCRB0403) from the Japanese Collection of Research Bioresources Cell Bank. Huh7 is an **immortalized cell line** available for research studies extracted from a human liver tumor in 1982.

# Virus irradiation

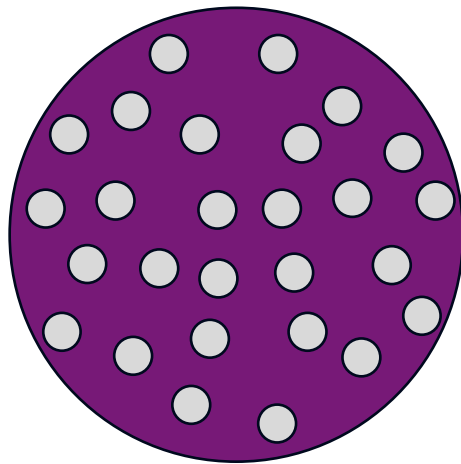
- Virus samples irradiated from 0.8 GHz to 40 GHz discretized into 10 sub-bands
- 10 discrete frequency points per sub-band
- 45 sec. dwell time per frequency point
- 33 dBm RF power
- Virus samples split into experimental and control groups
- Each Virus sample is used to infect a Huh7 plaque assay
- Tests conducted in triplicate → over 60 plaque assays



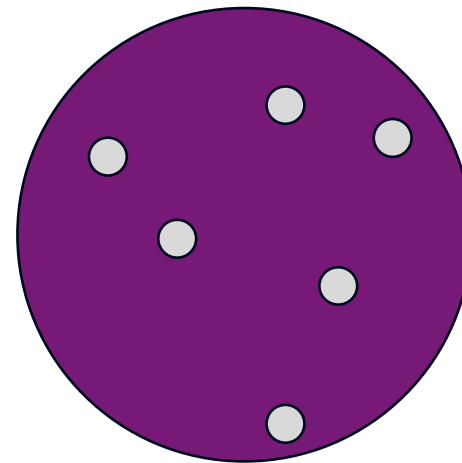
## Viral infectivity assessment: Plaque assay method

- Huh7 cells transferred to plates
- $3.5 \times 10^5$  Huh7 cells/plate and infected with HCoV-229E
- Cells incubated for 4 days post infection
- Cells were fixed and stained with a crystal violet solution for plaque visualization
- Plaques were counted to determine the viral titer.

4 days later....



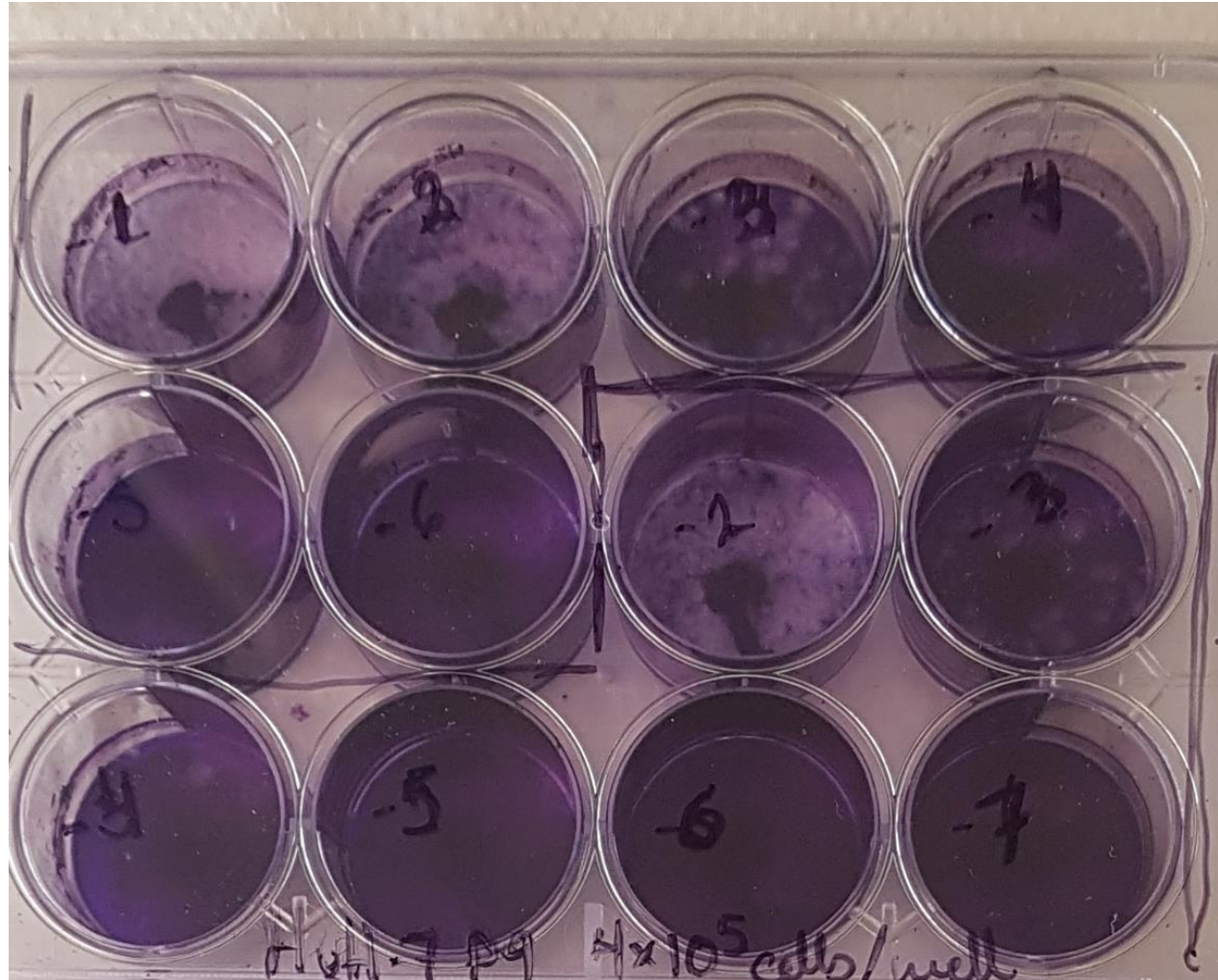
high viral infectivity



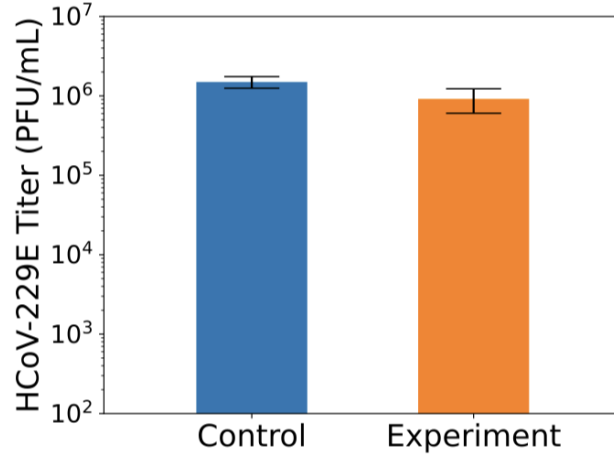
low viral infectivity

# Findings

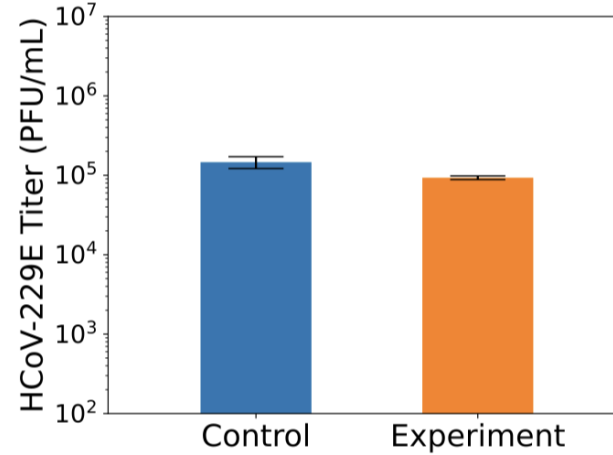
# HCoV-299E Plaque Assay



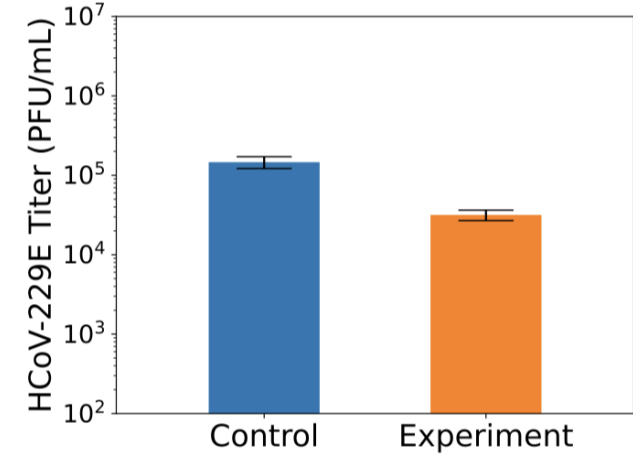
# Virus deactivation results



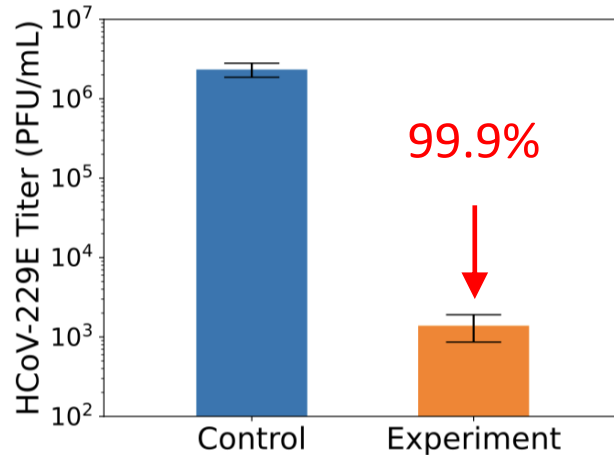
(d) WR 137 (5.9 GHz - 8.2 GHz)



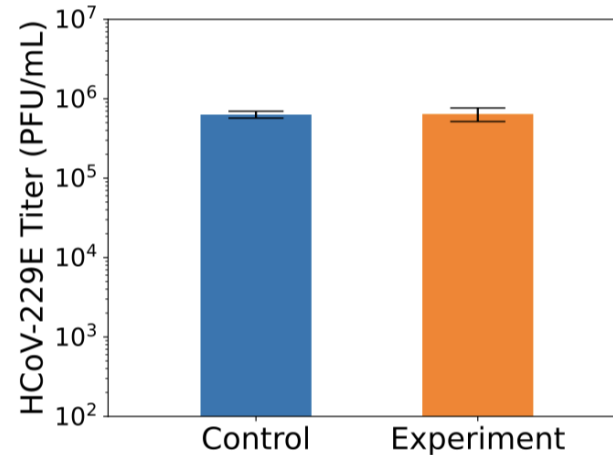
(e) WR90 (8.2 GHz - 12.4 GHz)



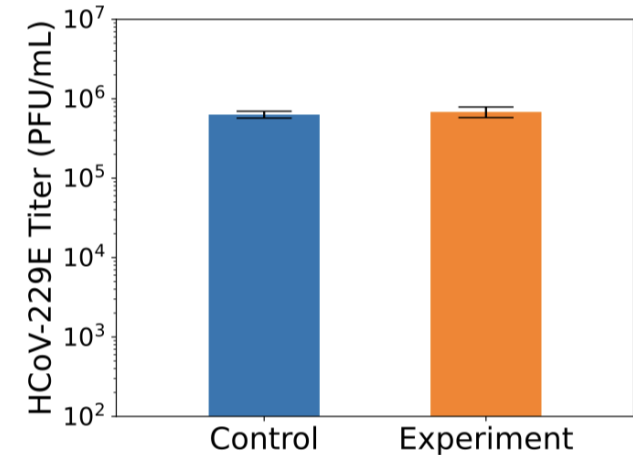
(f) WR62 (12.4 GHz - 15.0 GHz)



(g) WR62 (15.0 GHz - 19.5 GHz)



(h) WR42 (20.0 GHz - 26.5 GHz)



(i) WR28 (26.5 GHz - 33.5 GHz)

# Lab Results

WR Designation	Spectral Range (GHz)	Sample Heating ( $^{\circ}$ C)	Viral Reduction (-)
Reduced WR975	0.8 - 1.8	0	insignificant
WR284	2.1 - 4.4	0	insignificant
WR187	3.4 - 6.4	5	insignificant
WR137	5.9 - 8.2	7	insignificant
WR90	8.2 - 12.4	15	insignificant
WR62	12.4 - 15.0	10	1-log
WR62	15.0 - 19.5	2	3-log
WR42	20.0 - 26.5	3	insignificant
WR28	26.5 - 33.5	3	insignificant
WR28	33.5 - 40.0	3	insignificant

For further details...

[www.nature.com/scientificreports](https://www.nature.com/scientificreports)

**scientific** reports

 Check for updates

OPEN **Electromagnetic deactivation  
spectroscopy of human coronavirus  
229E**

Hayden Banting<sup>1✉</sup>, Ian Goode<sup>1</sup>, Carla E. Gallardo Flores<sup>2</sup>, Che C. Colpitts<sup>2</sup> &  
Carlos E. Saavedra<sup>1</sup>



## Discussion

- We have shown that HCoV-229E after a short-duration exposure to microwave signals in the 15 - 19.5 GHz band is deactivated through SRET and not through microwave heating
- Following the techniques developed in this study, the deactivation power level and frequency bands for other viruses of interest can be found
- Virus deactivation through SRET is non-contact, chemical-free and non-thermal, which has significant benefits for decontamination/sterilization of objects without compromising their durability or mechanical integrity

# Acknowledgments



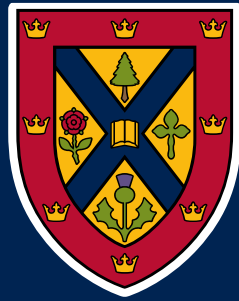
National  
Defence

Défense  
nationale



**IDEaS**

INNOVATION FOR DEFENCE  
EXCELLENCE AND SECURITY



Queen's  
UNIVERSITY

# 6-18+ GHz amplifier



COAXIAL

## High Power Amplifier **ZVE-3W-183+**

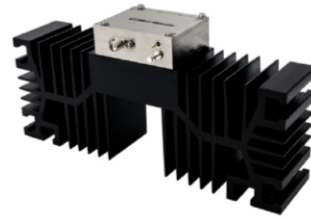
50Ω 3W 5.9 to 18 GHz

### THE BIG DEAL

- High power, 3 Watt
- Wideband, 5.9 to 18 GHz
- High IP3, +44 dBm typ.
- High dynamic range
- High gain, 35dB typ.
- Internal voltage regulated for 13 to 18VDC

### APPLICATIONS

- Radar
- Video and test instrumentation
- Booster amplifiers for lab test equipment

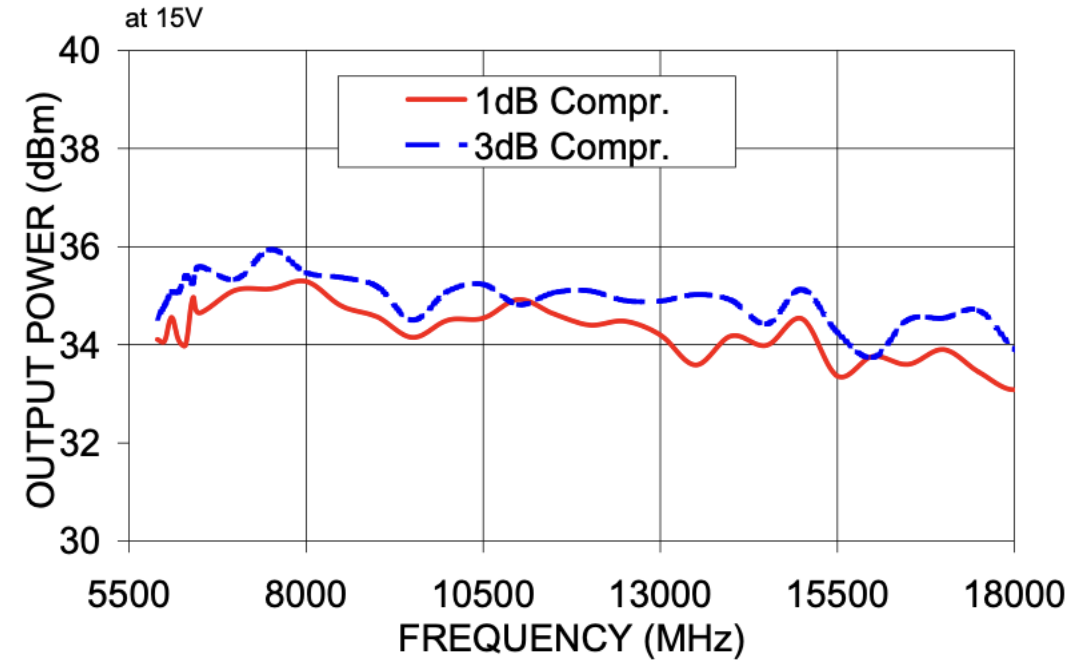


Generic photo used for illustration purposes only

Model No.	ZVE-3W-183+
Case Style	DN1327
Connectors	SMA-Female


**+RoHS Compliant**

The +Suffix identifies RoHS Compliance. See our web site for RoHS Compliance methodologies and qualifications



# 20-40 GHz GaN Power Amplifier



<b>Part Number:</b>	QPA2640D
<b>Manufacturer:</b>	Qorvo
<b>Export Status:</b>	 <b>Restricted</b>
<b>Type:</b>	MMIC Amplifiers
<b>Frequency Min:</b>	20 GHz
<b>Frequency Max:</b>	40 GHz
<b>Psat:</b>	39 dBm
<b>Gain:</b>	22 dB
<b>Quiescent Current \ Id:</b>	2040 mA
<b>Package:</b>	DIE
<b>Power Added Efficiency:</b>	12 %
<b>Return Loss Input:</b>	7 dB
<b>Return Loss Output:</b>	7 dB
<b>Process:</b>	GaN