Asymmetric SRF dual axis cavity for ERLs: studies and design for ultimate performance and applications

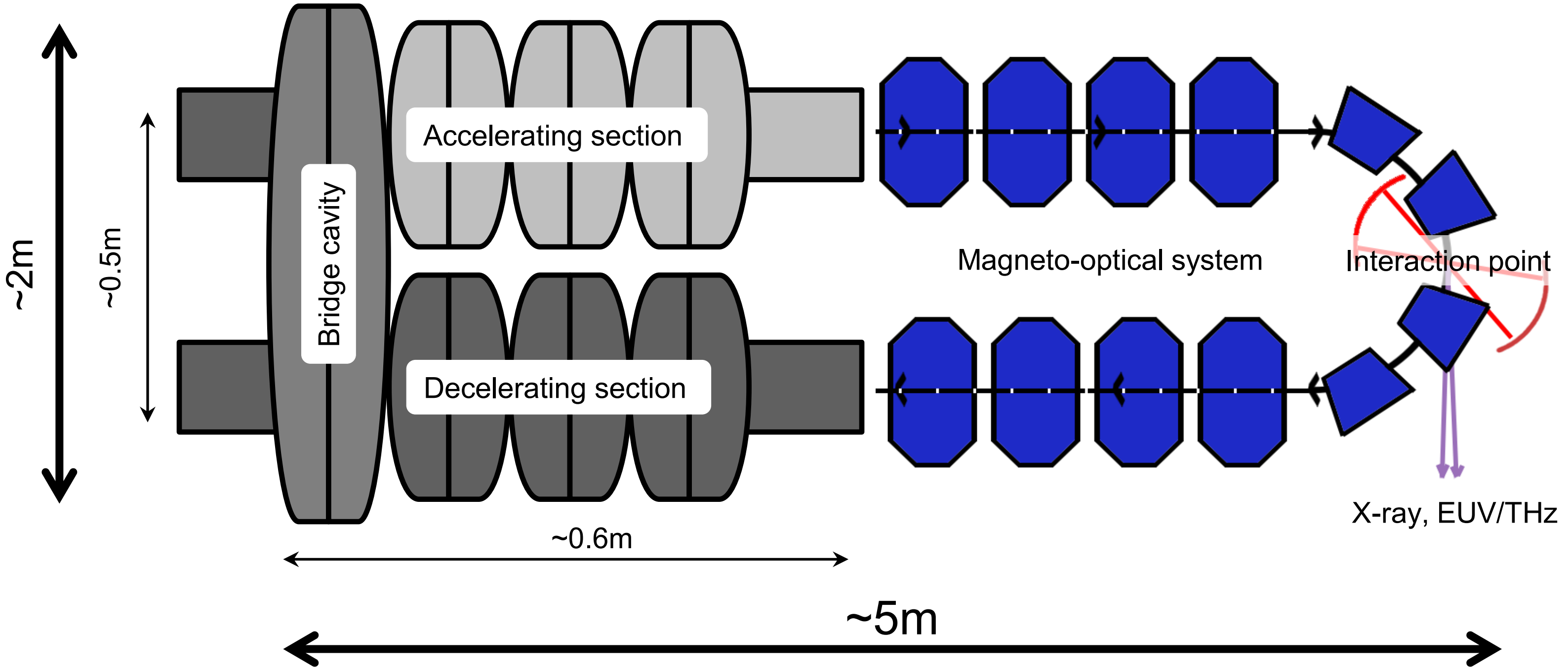
I. V. Konoplev[1], M. Topp-Mugglestone[1]
Ya. Shashkov[2], A. Bulygin[2]
F. Marhauser[3], A. Seryi[3]

[1] JAI, Department of Physics, University of Oxford
[2] National Research Nuclear University MEPhI
[3] Thomas Jefferson National Accelerator Facility

UH-FLUX: AERL

Aim:To surpass any existing designs of ERL in the e-beam current handling capabilities and footprint

Scientific Impact: High Current ERL for Compton light source and FEL

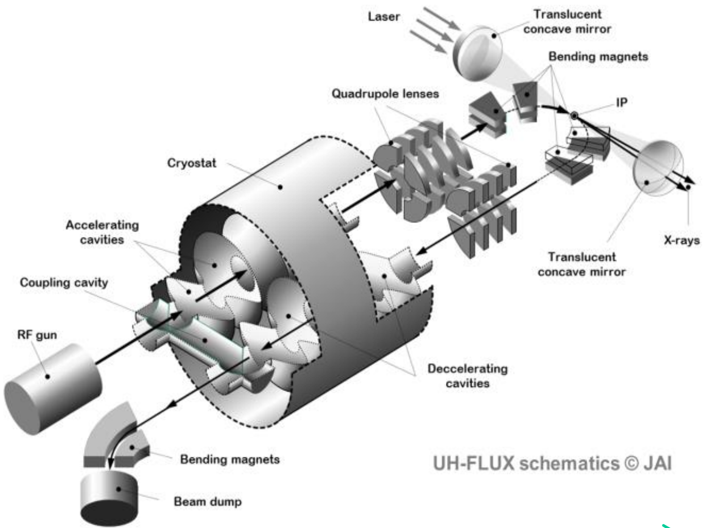


UH- FLUX: compact source of THz and EUV radiation

Very large current designs

100 metre +

AERL

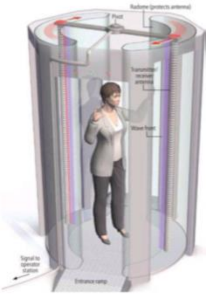


5 metre

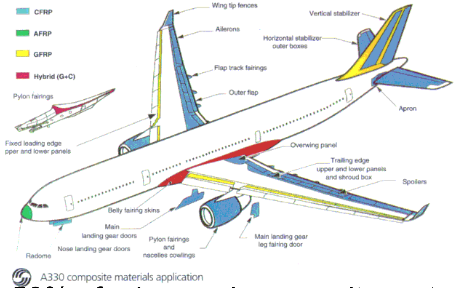
Applications

Application in Ultra-High Intensity source of coherent radiation

THz Application: security control



Quality and contents



>50% of advanced composite materials

<u>THz Application</u>: Produce radiation at high power (up to 1MW) from 0.1 THz to 10 THz

Markets (outside research laboratories):

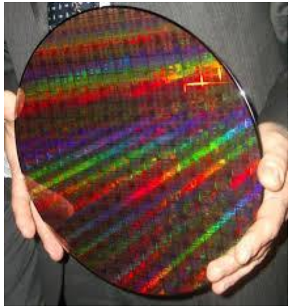
- Cargo Screening: The World Market for Explosives, Weapons, and Contraband Detection Equipment (EWC) is estimated to be some $2.1 billion annually[1]
- Replacing X-ray scanners: The global security screening market is expected to reach $9.10 Billion by 2020[2]
- Non-contact imaging of coatings and composites, material quality control, drug formulation

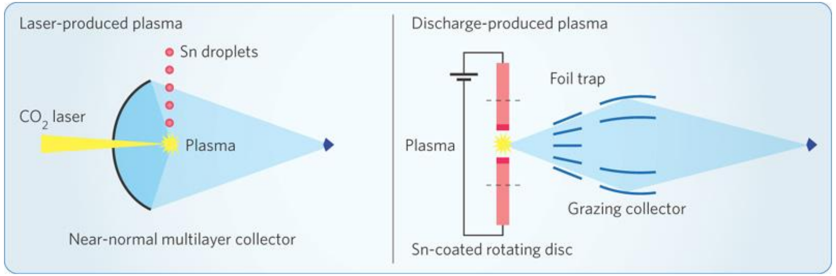
[1]The Market for Explosives, Weapons and Contraband (EWC) Detection Equipment – HIS Technology, 2014 Edition

[2]Security Screening Market - Analysis and Forecast 2013-2020 – MarketsandMarkets, 2014 Edition

Applications

EUV Applications: lithography - moving to ~10nm and QAs





EUV Applications: Generating electron beams of typical energy of 10-30 MeV and current above 1A to generate high flux (10^{18} -10^{20} photon per second) of radiation from 1nm to 10nm wavelengths range

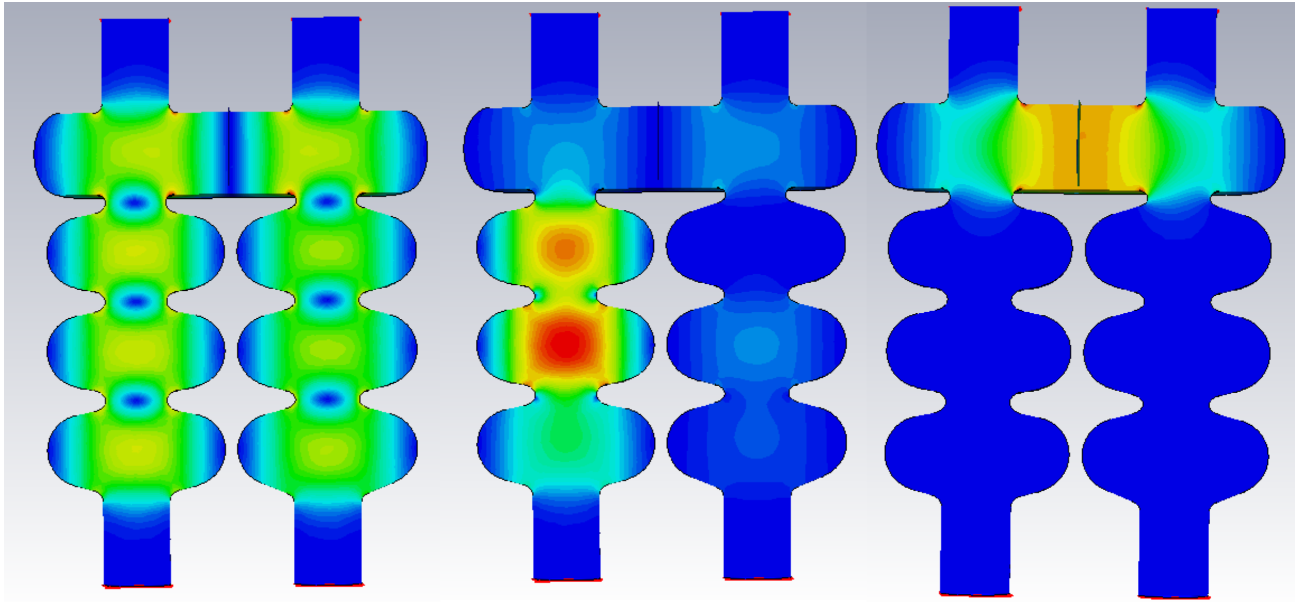
Markets (outside research laboratories):

- Non-destructive sources and material/medical diagnostics research market
- Lithography for the £332 billion Semiconductor Industry: $7 billion market in 2014[3]

[3]Investor Day, ASML Small Talk London - 2015

Proof of the concept experimental studies

UH-FLUX: AERL 7 Cell cavity



$f = 1.300144\ GHz$
Operating mode

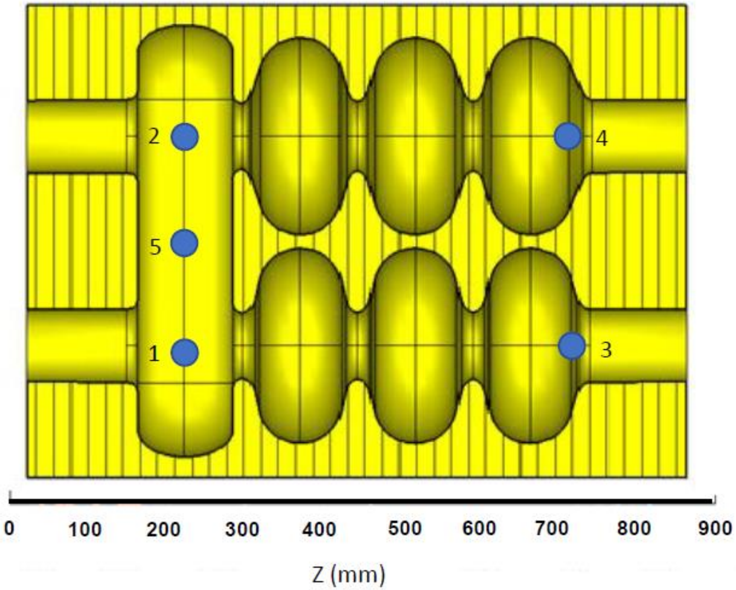
$f = 1.279688\ GHz$
Parasitic asymmetric mode

$f = 1.099712\ GHz$
Coupling bridge mode

Results observed using CST- Microwave studio

Experimental studies: proof of the concept

Aluminium 7 cells cavity

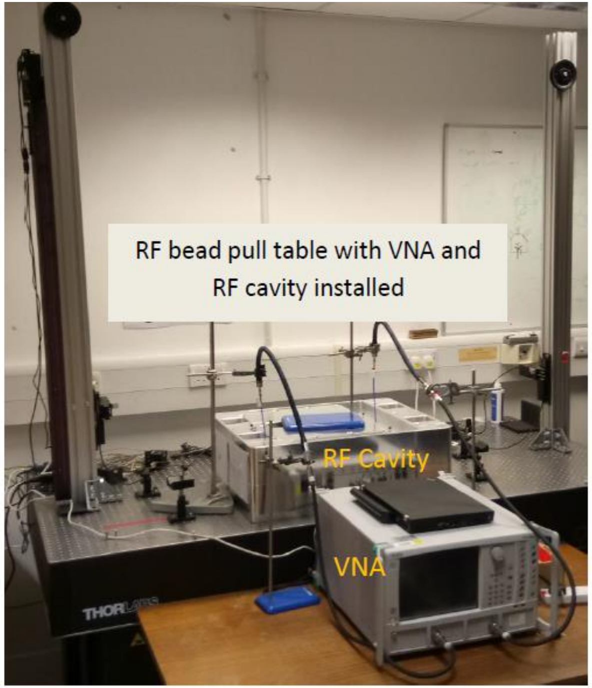


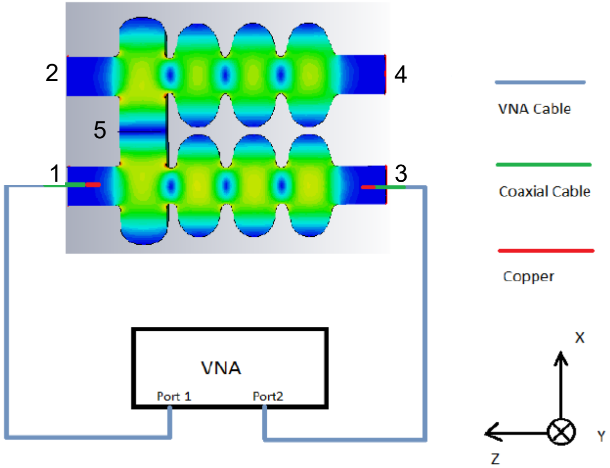
Aim:

- to identify the cavity modes: operating and HOMs
- to compare with numerical data

Starting measurements

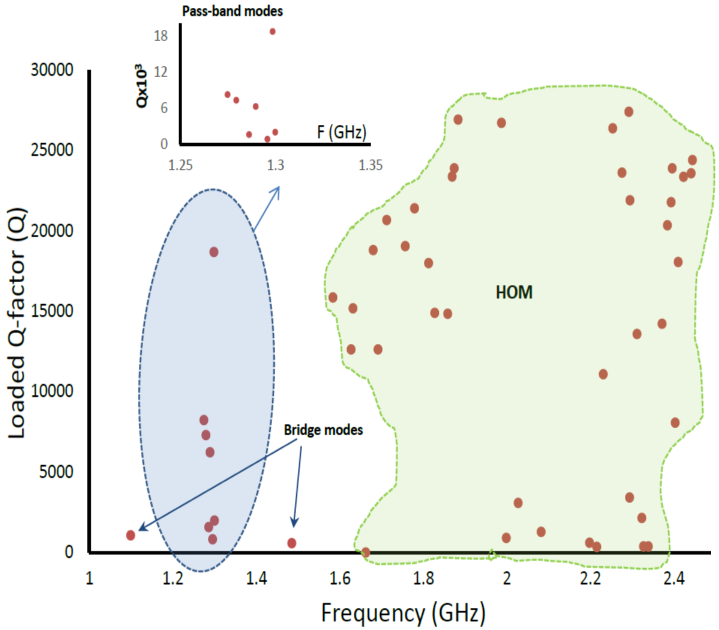
Measuring S_{11} and S_{21} parameters as well as field structure



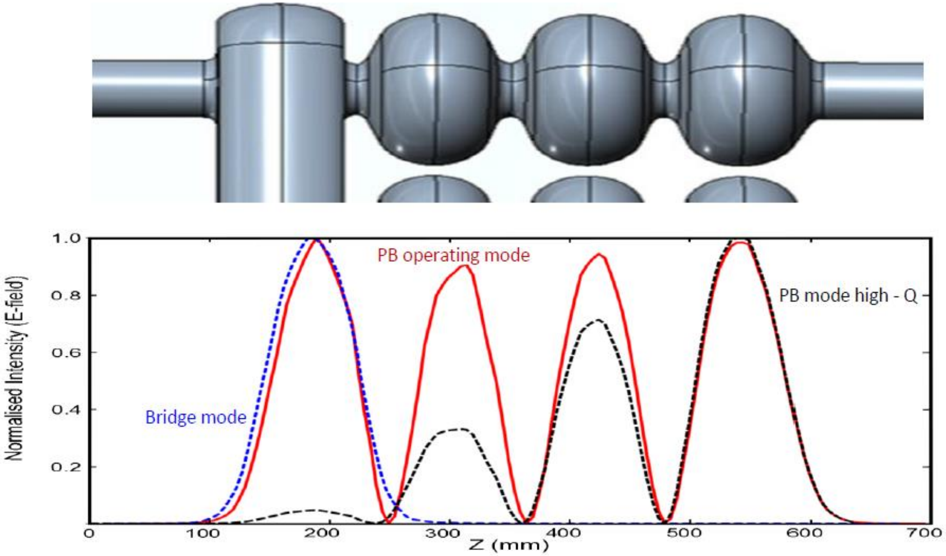


Eigenmodes of the 7- Cell cavity

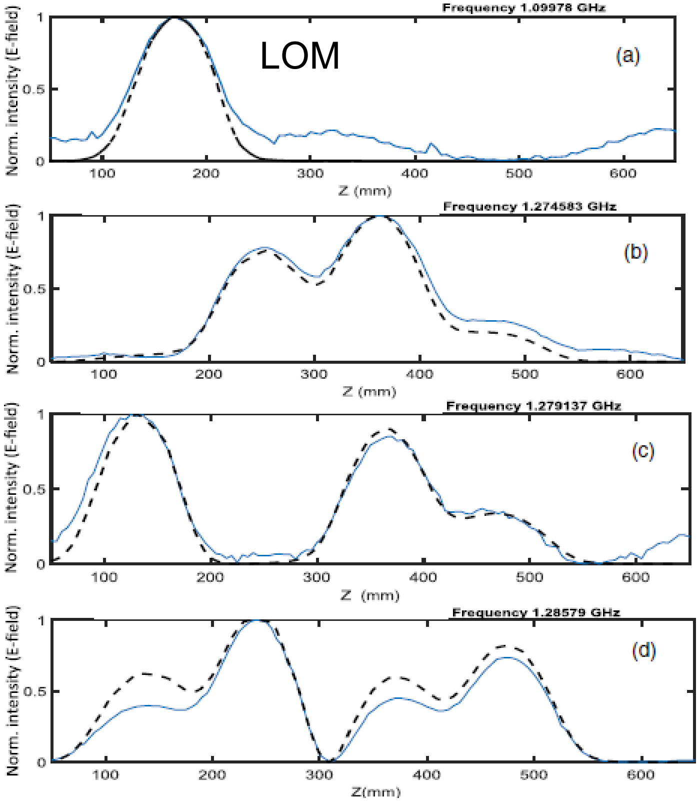
Predicted by CST Microwave studio



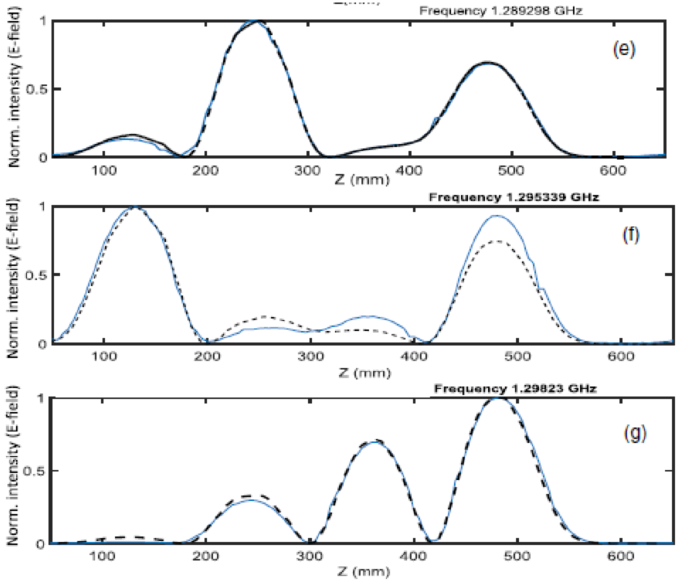
Field structures of the eigenmodes predicted by CST



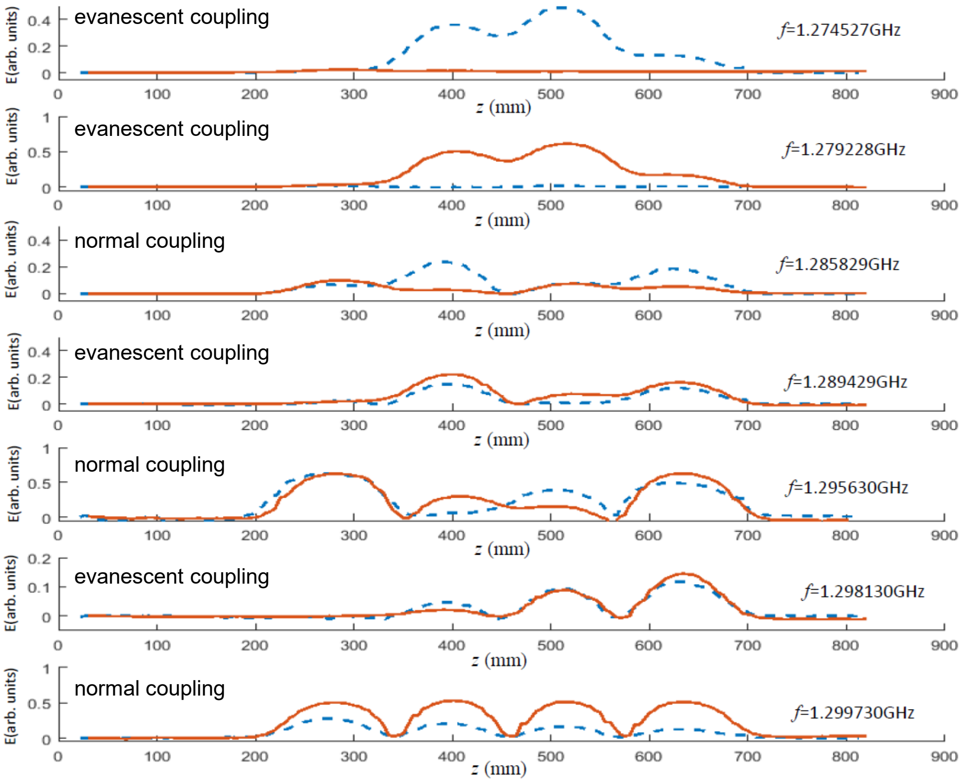
Pass band modes: experimental studies



First comparison of the pass band modes measured (solid line) with the numerical predictions dashed line. The measurements were carried out at a single axis.



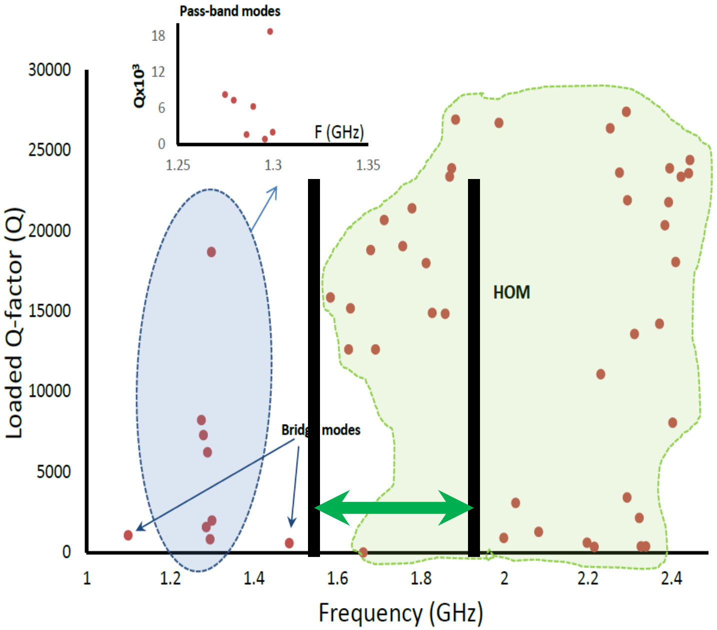
Pass band modes: experimental studies

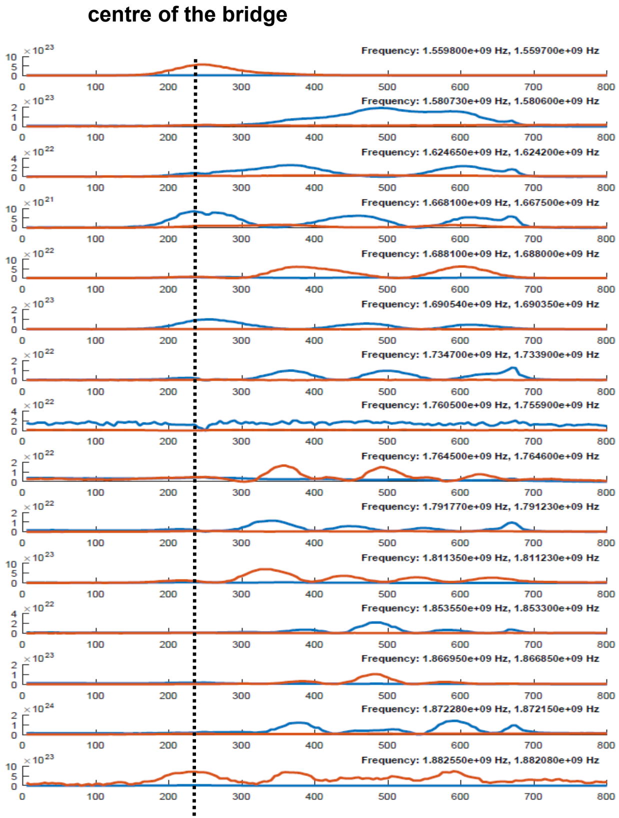


The RF coupler is located on one axis (active) while the field measurements are conducted on both axes

Red line active axis
Blue line passive axis

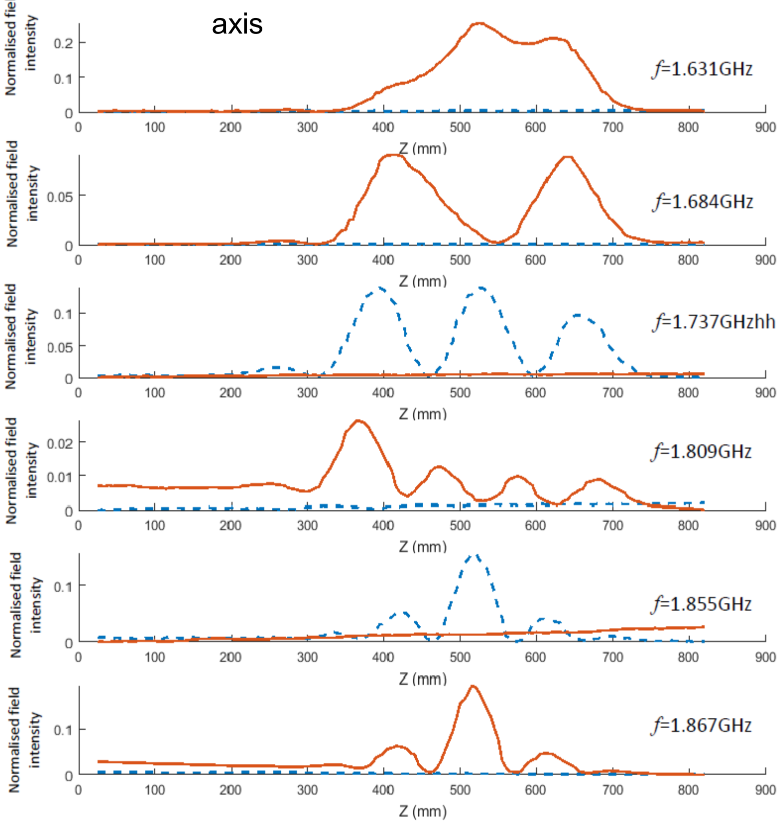
14 first HOMs and the Bridge mode





HOMs measurements

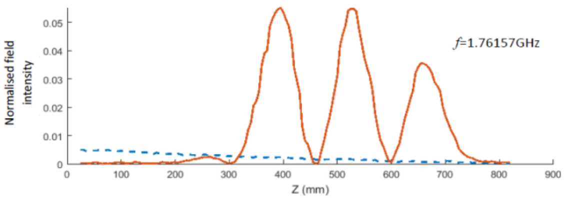
HOMs localisation at one or another axis

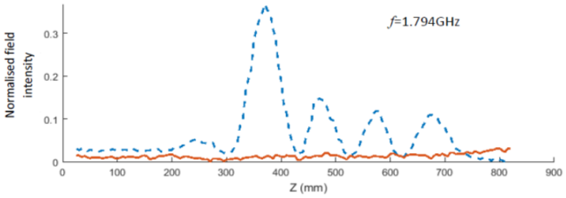


The RF coupler is located on one axis (active) while the field measurements are conducted on both axes

Red line active axis

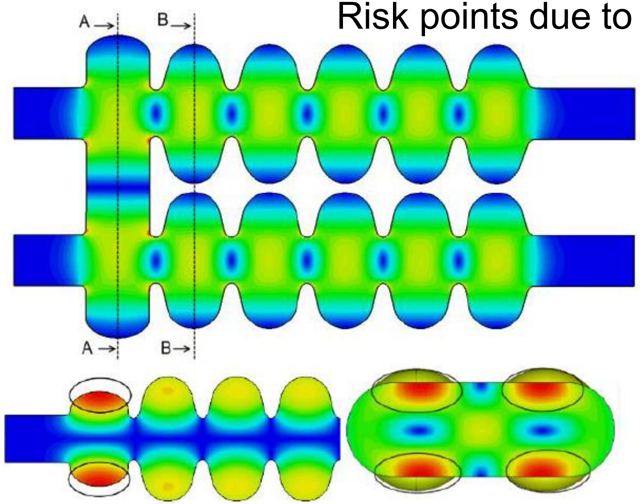
Blue line passive axis

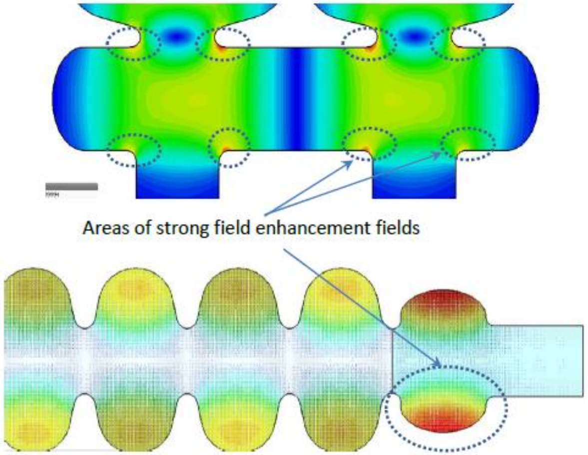




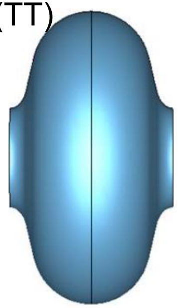
Cavity optimisation

Risk points due to high field intensity on the surface





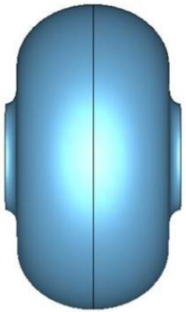
Tesla like cavity (TT)



Other risk factors:

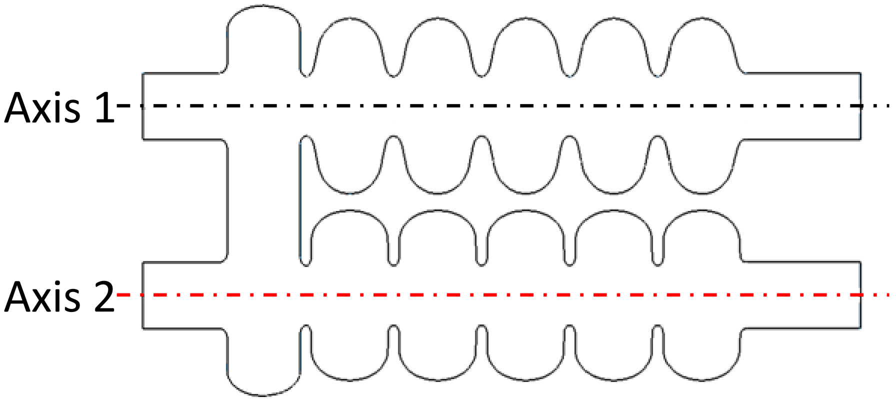
- Multipacting
- Proximity on modes to operating mode
- Cost

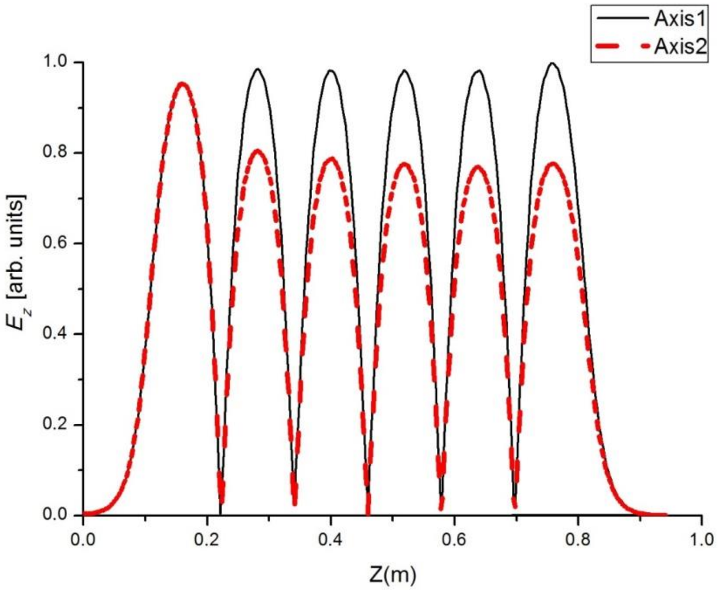
Low Loss like cavity (LL)



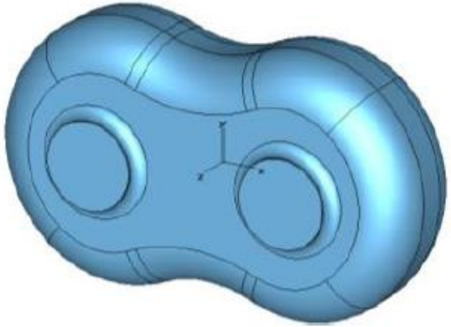
Cavity optimisation

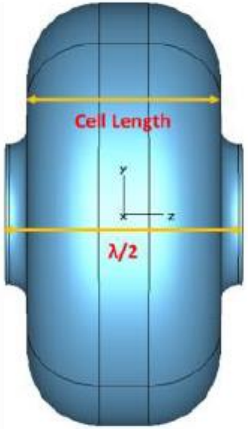
Tesla and Low loss cavity





JLAB dual axis cavity



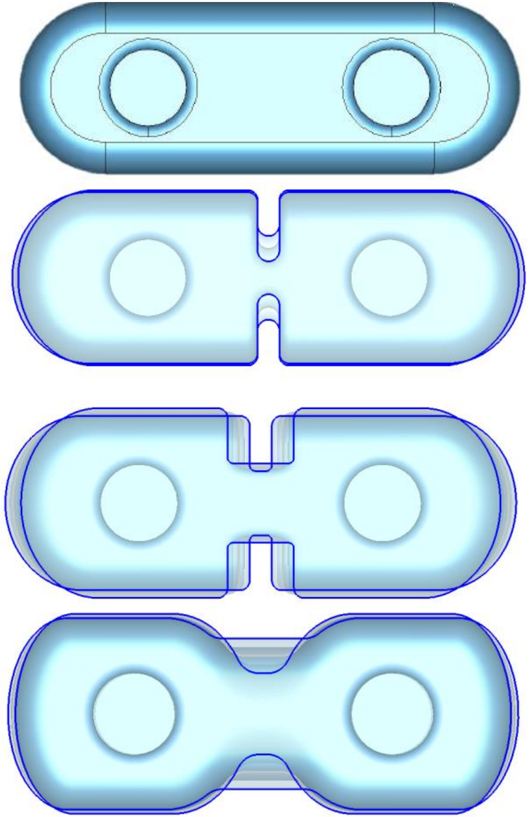


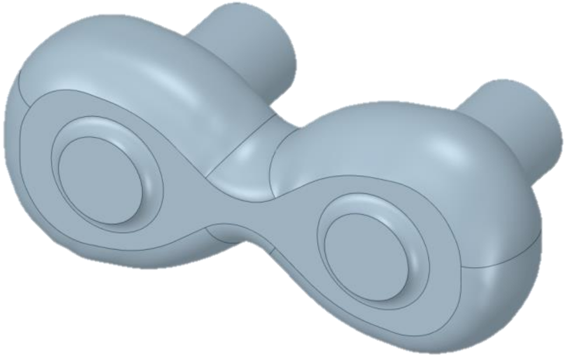
The cavity was used as a prototype during the optimisation
It was considered as an indication that such structure can be machined

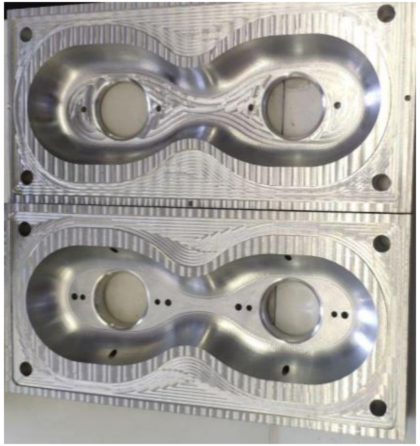
Parameter	Value	Units
Cavity height	202.5	mm
Cavity width	300.0	mm
Cavity length	100.13	mm
Cell length	81.13	mm
Iris curvature	8.0	mm
Beam aperture	60.0	mm
Beam axis separation	136.5	mm
V_{acc}	0.1	MV
$E_p/E_{acc}{}^*$	2.68	
$B_p/E_{acc}{}^*$	5.5	mT/(MV/m)
$[R/Q]$	60.1	Ω
G	320.8	Ω
R_tR_s	1.93×10^4	Ω^2
LOM	1103	MHz
Nearest HOM	1806	MHz
V_t	26.4	V

*At E_{acc} = 1 MV/m

Bridge optimisation







- Resolved high field risk
- Improved the modes proximity
- Resolve the challenge with multipacting

	Initial new bridge 11 cells/ TT end reg	U – структура 11 cells TLL end reg
Operating mode Frequency (GHz)	1.299995	1.299961
Nearest mode frequency (GHz)	1.299485	1.299418
E_p/E_a	2.91	2.28 (more than 20% improvement)
$B_p/E_a\,(mT/MV/m)$	6.32	4.43 (around 30% improvement)
R/Q (Ohm) axis 1	330	406
R/Q (Ohm) axis 2	333	273
V_z (MV) axis 1	1.65	1.82
V_z (MV) axis 2	1.64	1.49
R/Q (Ohm) - axis 1 nearest mode	249	196
R/Q (Ohm) - axis 2 nearest mode	240	338

Conclusion

- The aluminium (7-cells) and copper (11-cells) dual axis asymmetric cavities were constructed
- Preliminary studies of HOMs and path-band modes were carried out and HOMs localisation has been demonstrated
- The first design of the SRF dual axes asymmetric cavity has been completed

Thank you!