Recent Production of Intense High Charge Ion Beams with VENUS

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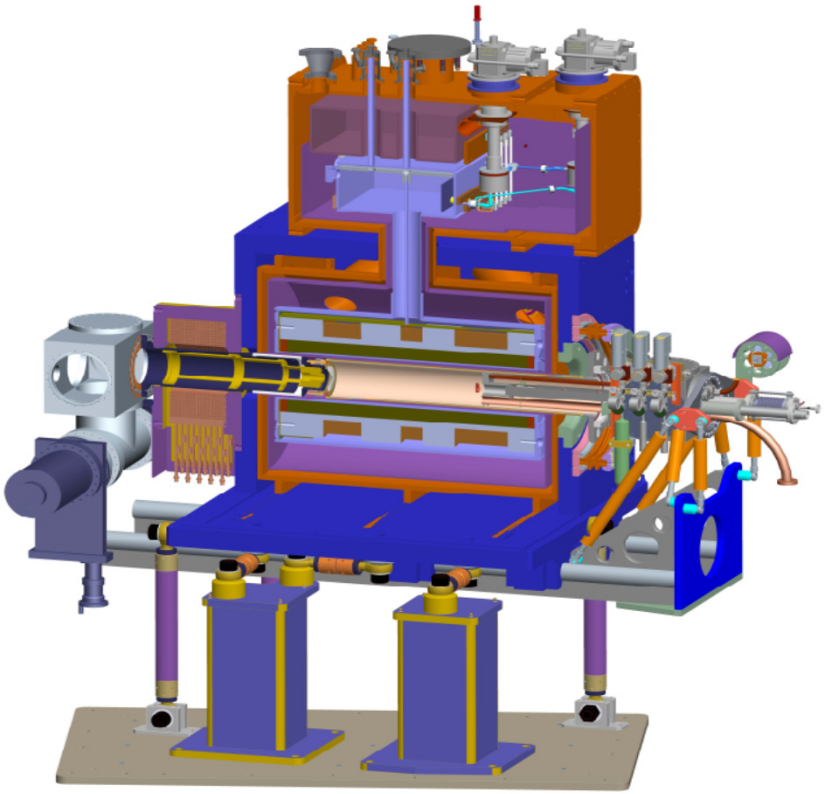
- **Recent VENUS performance**
- ***How was the enhancement achieved***
- ***Discussions and conclusions***

VENUS: The first 3rd Generation ECRIS

B_{max} on axis: 4 T, B_r at chamber wall: ~2 .2 T, operating at 28+18 GHz



VENUS

First plasma in 2002.

Previous VENUS performance and Comparison

(Quoted currents are in unit of emA)

	VENUS 28+18 GHz (≤ 2015, ≤ 8 kW)	SECRAL 24+18 GHz	SuSI 24+18 GHz
$^{16}O^{6+}$	2.85	**2.3**	2.2
O^{7+}	0.85	**0.81**	1.4
$^{40}Ar^{12+}$	0.86	**1.42**	0.86
Ar^{14+}	0.514	**0.846**	0.53
Ar^{16+}	0.27	**0.35**	0.22
Ar^{17+}	0.037	**0.05**	
Ar^{18+}	0.001		
$^{78}Kr^{18+}$	^{84}Kr		
Kr^{23+}	0.088		
Kr^{28+}	0.025		
Kr^{31+}			
$^{129}Xe^{27+}$	0.40	**0.92**	
Xe^{30+}	0.21	**0.322**	
Xe^{34+}	0.05	**0.09**	
Xe^{38+}	0.007		
$^{209}Bi^{30+}$	0.31	**0.71**	
Bi^{36+}	0.09	**0.32**	
Bi^{45+}	0.018	**0.049**	
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(Quoted currents are in unit of emA)

	VENUS 28+18 GHz (≤2015, 8 kW)	VENUS 28+18 GHz (~ 2016, 10 kW)	SECRAL 24+18 GHz	VENUS Improvement 2016/2015
$^{16}O^{6+}$	2.85	**4.75**	**2.3**	**1.67**
O^{7+}	0.85	**1.90**	**0.81**	**2.23**
$^{40}Ar^{12+}$	0.86	**1.06**	**1.42**	**1.23**
Ar^{14+}	0.514	**0.84**	**0.846**	**1.63**
Ar^{16+}	0.27	**0.523**	**0.35**	**1.94**
Ar^{17+}	0.037	**0.115**	**0.05**	**3.11**
Ar^{18+}	0.001	**0.004**		**4.0**
$^{78}Kr^{18+}$	^{84}Kr	**0.77**		
Kr^{23+}	0.088	**0.42**		**4.77**
Kr^{28+}	0.025	**0.089**		**3.56**
Kr^{31+}		**0.007**		**∝**
$^{129}Xe^{27+}$	0.40	***Plasma***	**0.92**	
Xe^{30+}	0.21		**0.322**	
Xe^{34+}	0.05	***Stability!!!***	**0.09**	
Xe^{38+}	0.007			
$^{209}Bi^{30+}$	0.31		**0.71**	
Bi^{36+}	0.09		**0.32**	
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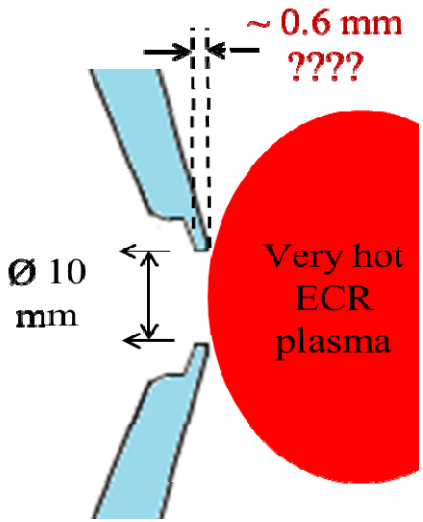
Remedy 1 VENUS thin edged plasma electrode insufficiently transported away the power generated by hot electrons



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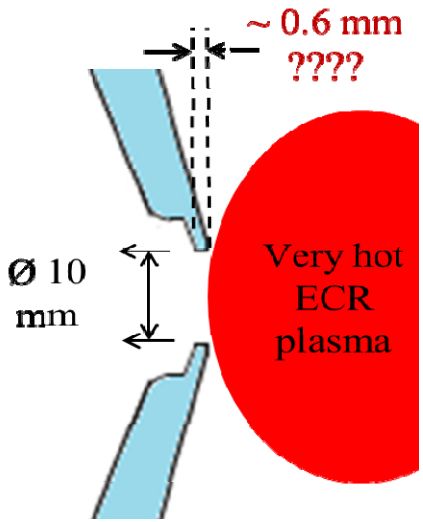

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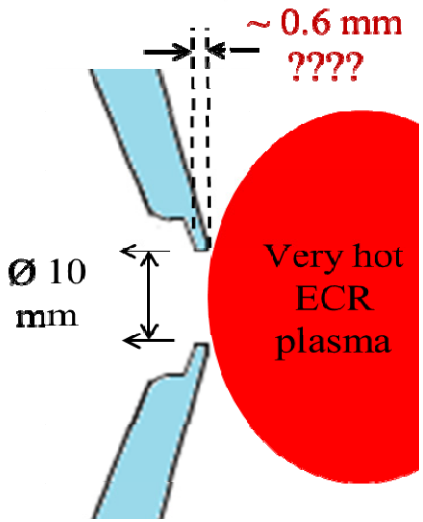
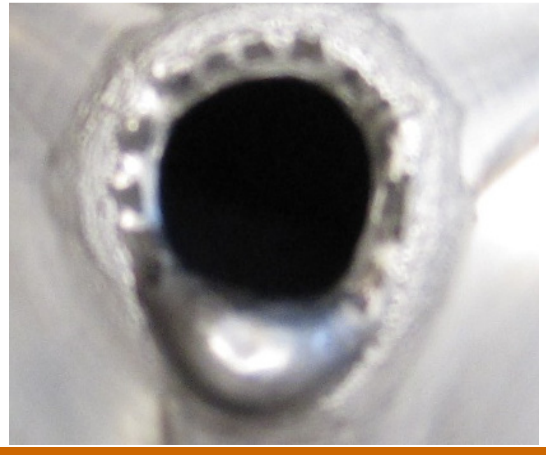


7.5 kW, a few hours of operation



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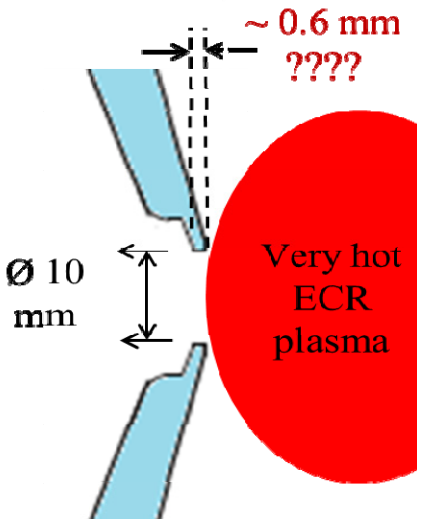

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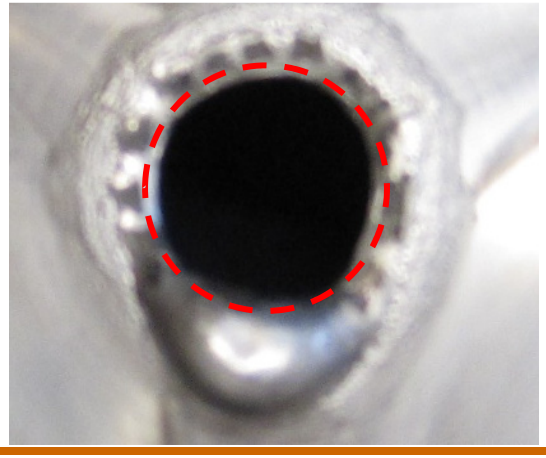

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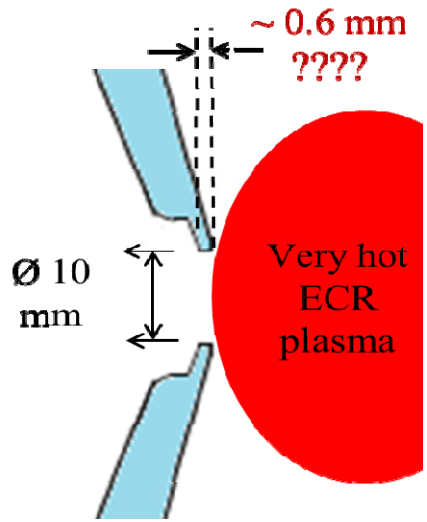

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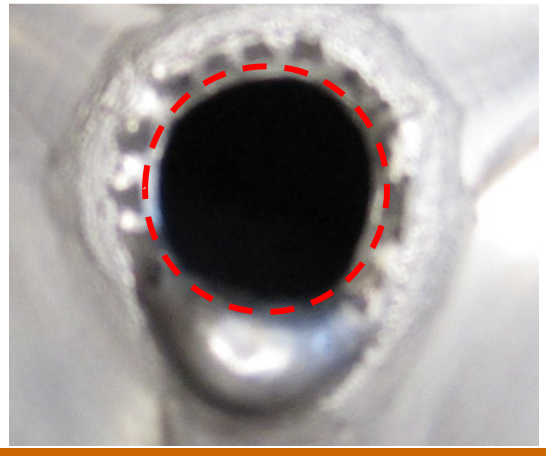

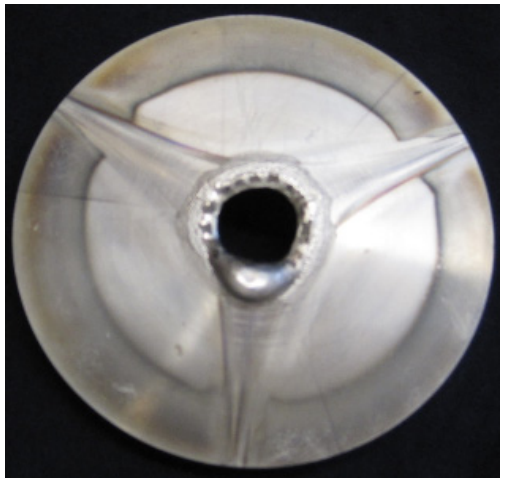

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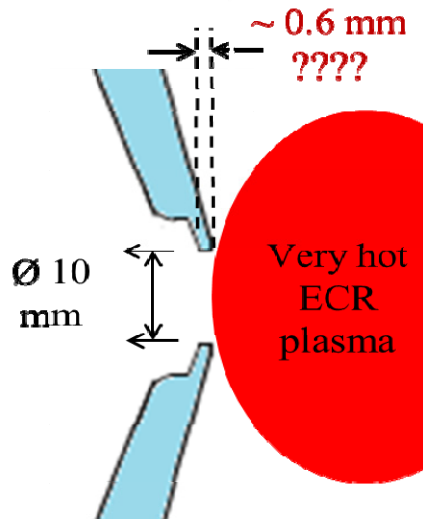

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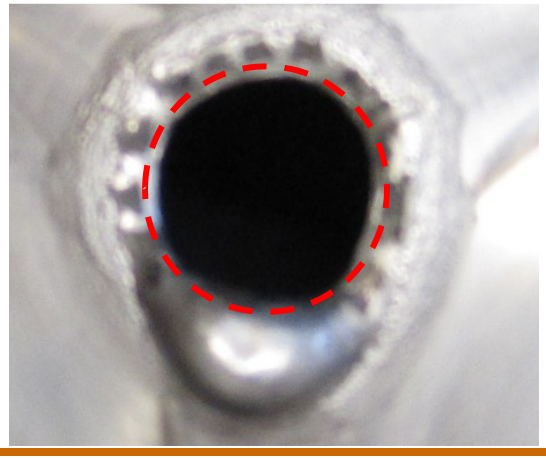

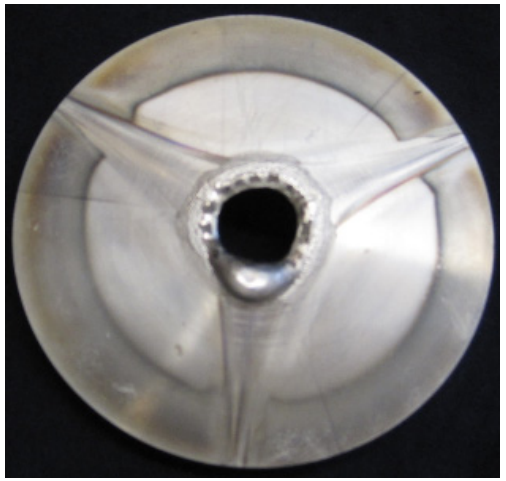

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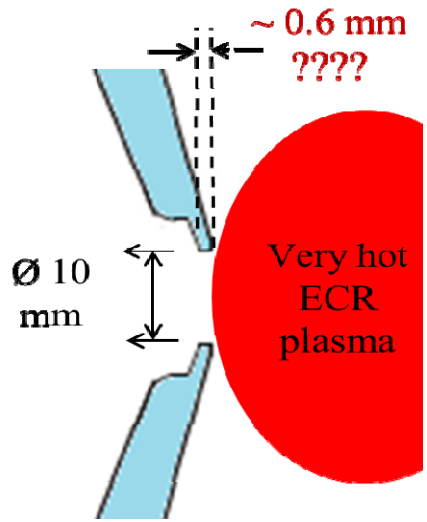

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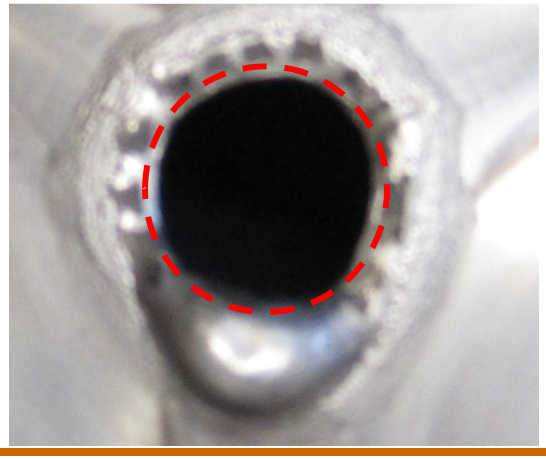

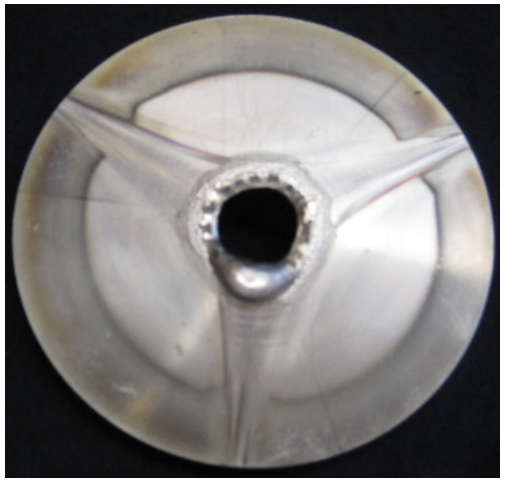

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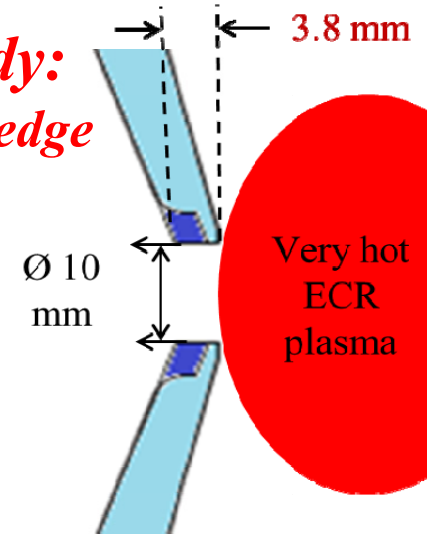

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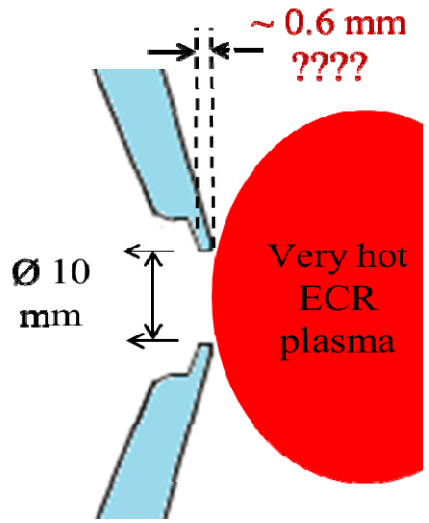

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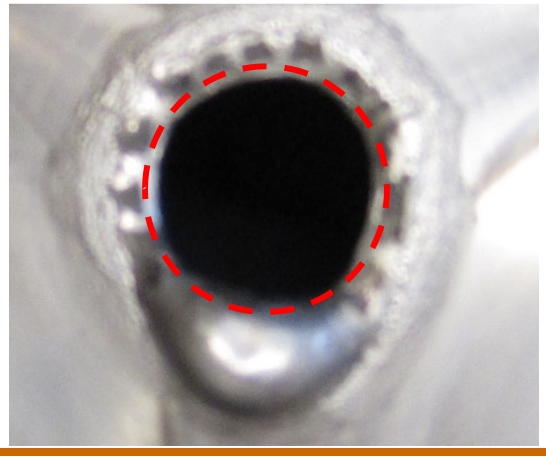

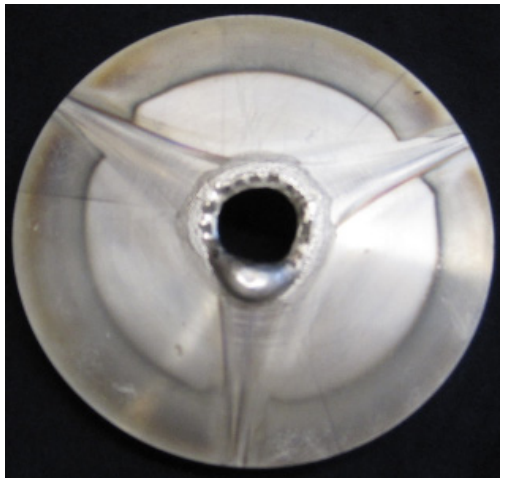

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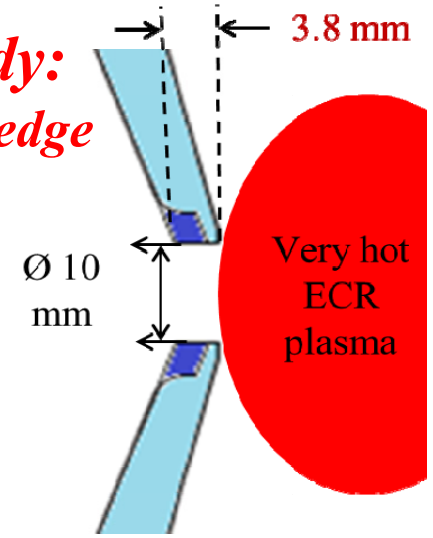

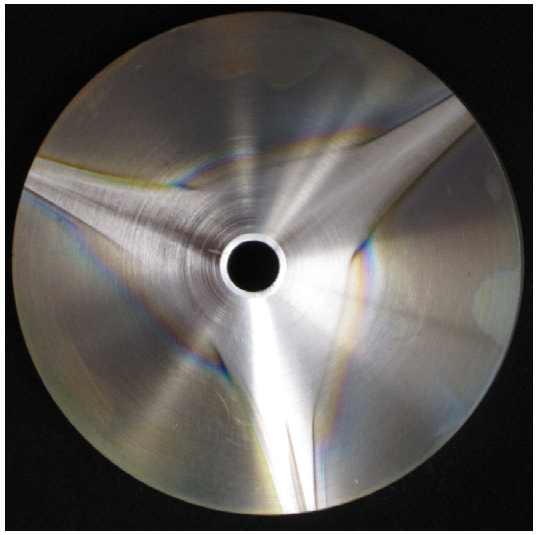

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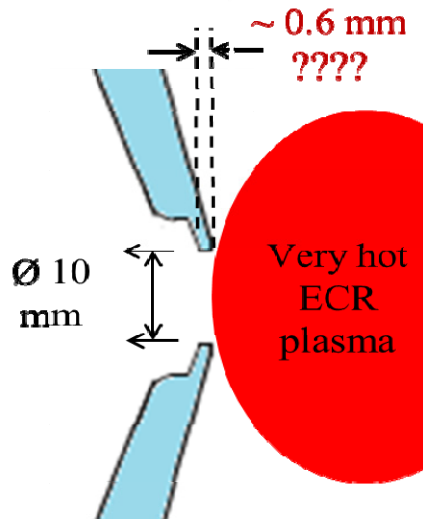

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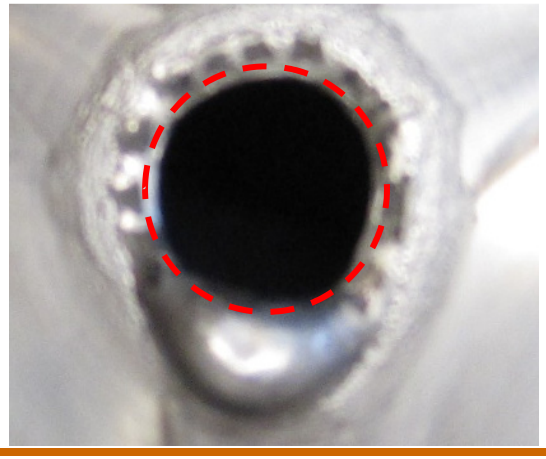

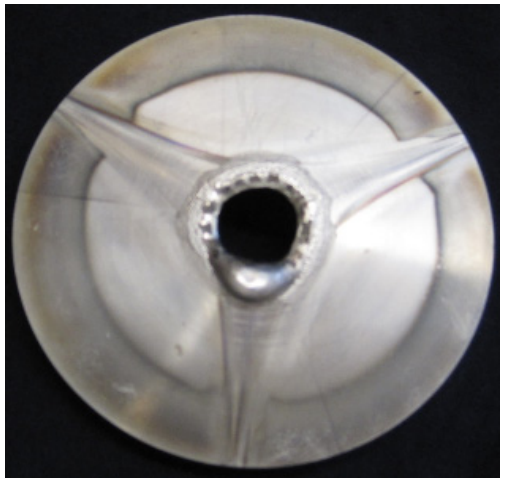

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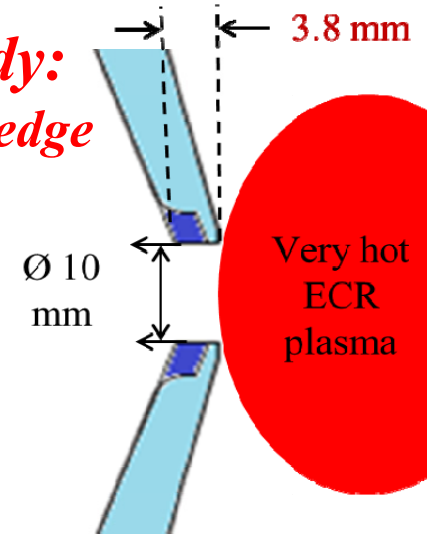
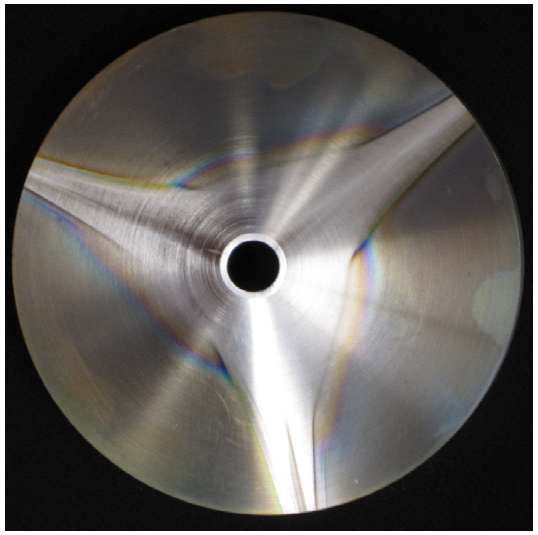
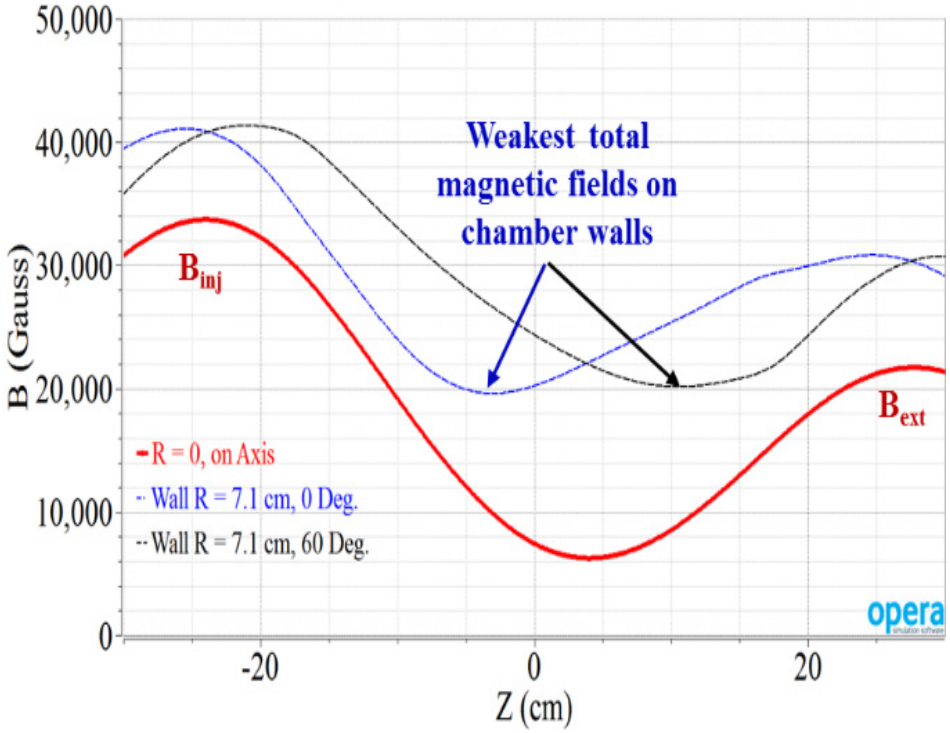




~ 10 kW, months of operations. Little corrosions

Two VENUS chambers burned



VENUS had been operating for many years with constrained magnetic field configurations like the one is shown. There were always magnetic holes on the plasma chamber walls due to the peak field at extraction is higher than the total fields at some locations of the walls.

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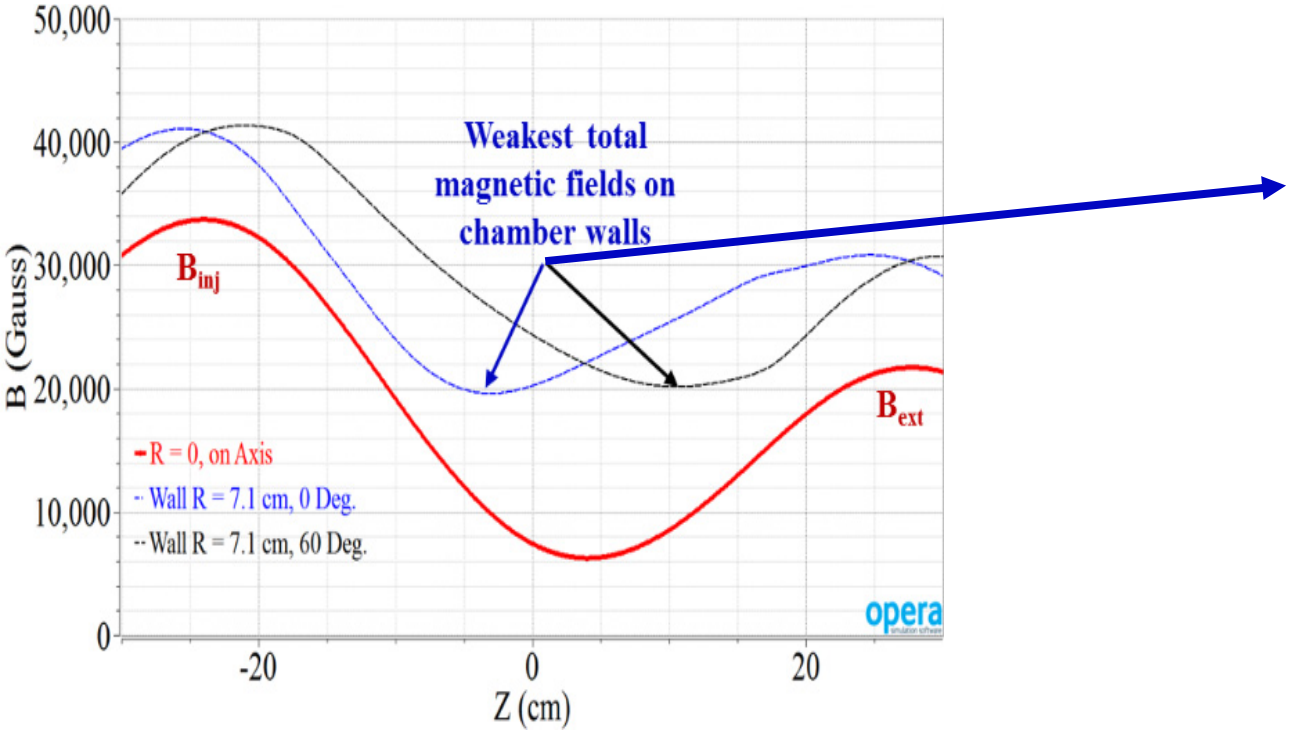

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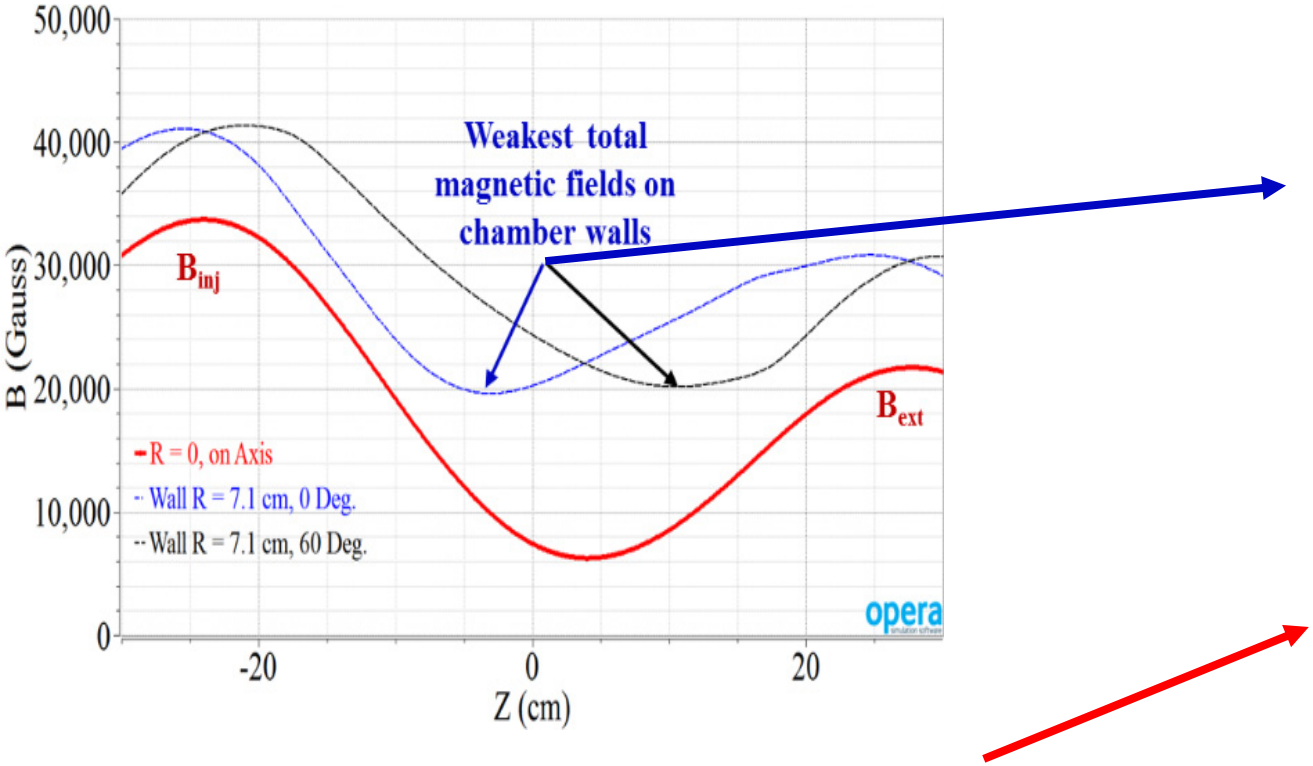

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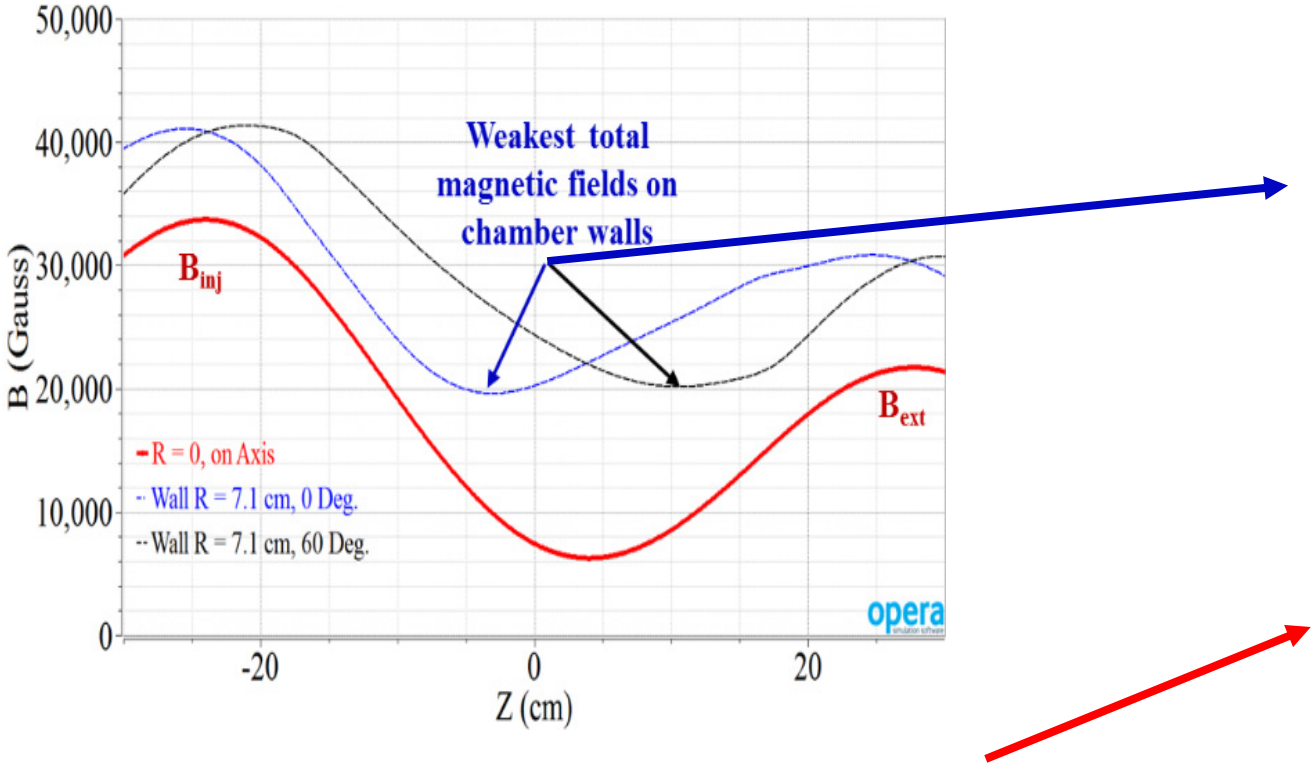

Easily for T ↑150 ^{0}C and then 350 ^{0}C.

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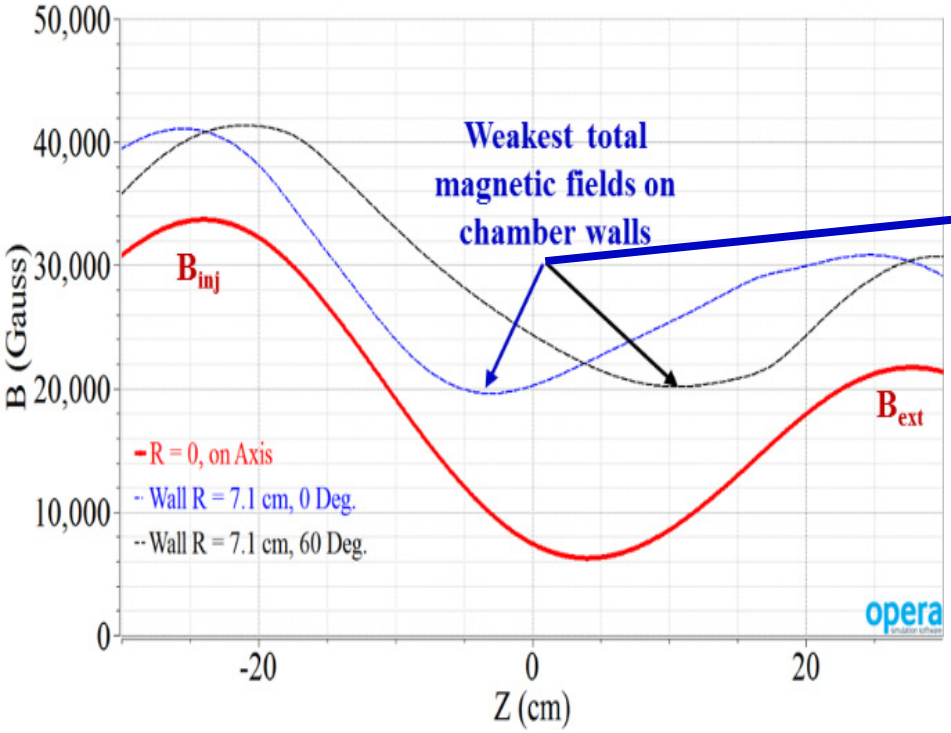

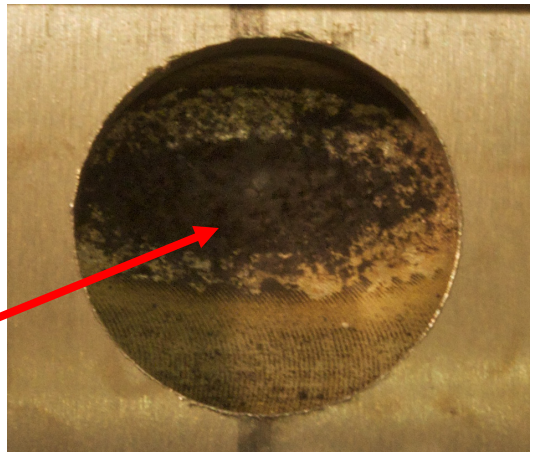

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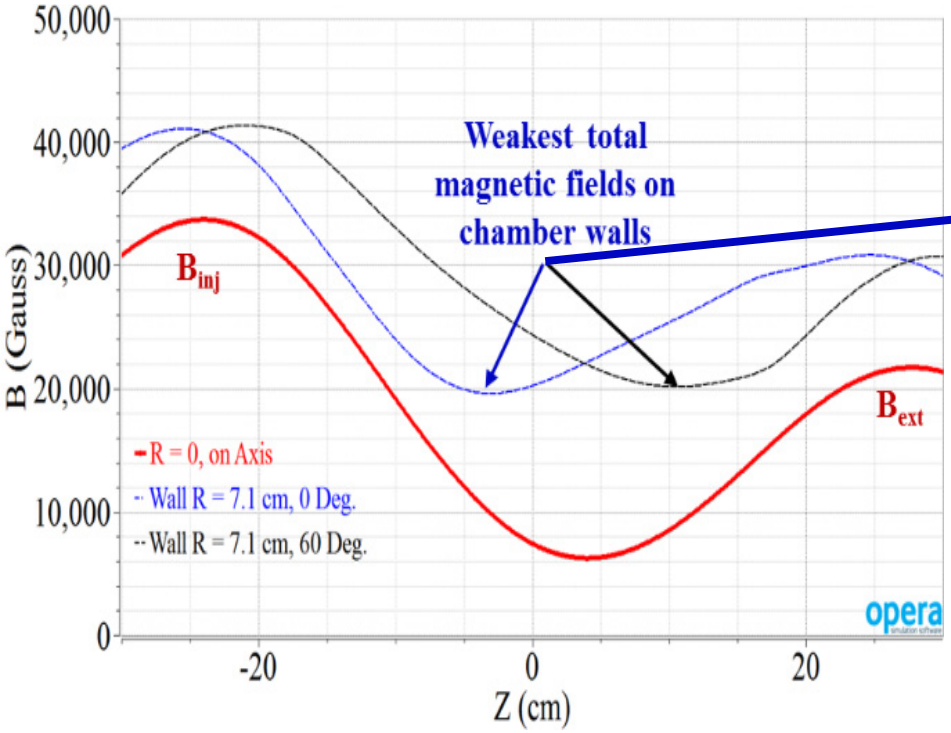

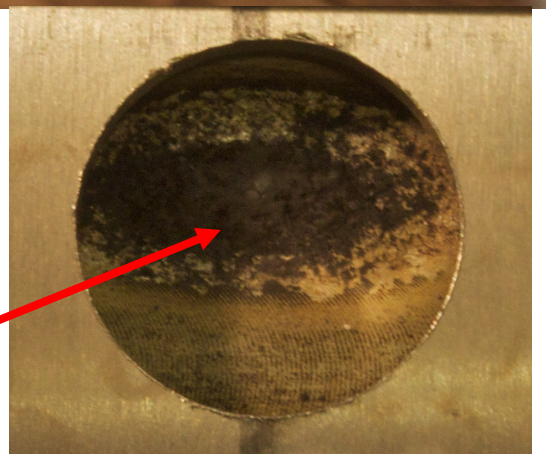

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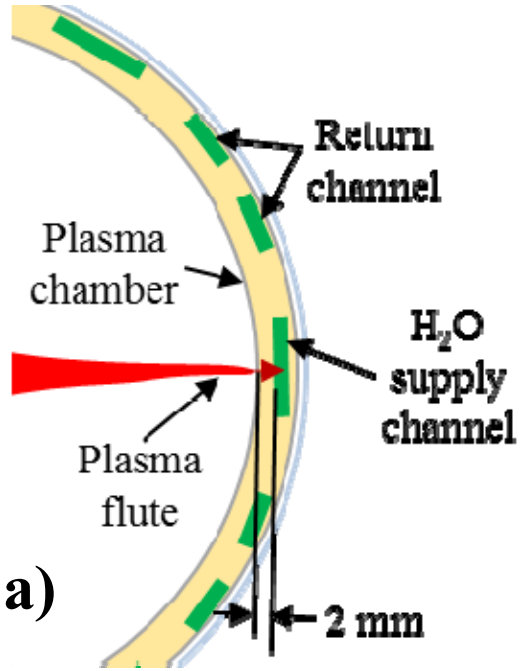
$P_e \uparrow 100$ *W/cm*^{2}. *Easily for* $T \uparrow 150\ ^0C$ *and then* $350\ ^0C$.



a). The previous plasma chamber cooling scheme aligned a water channel with ~ 2 mm thick wall right on a plasma flute (red colour).

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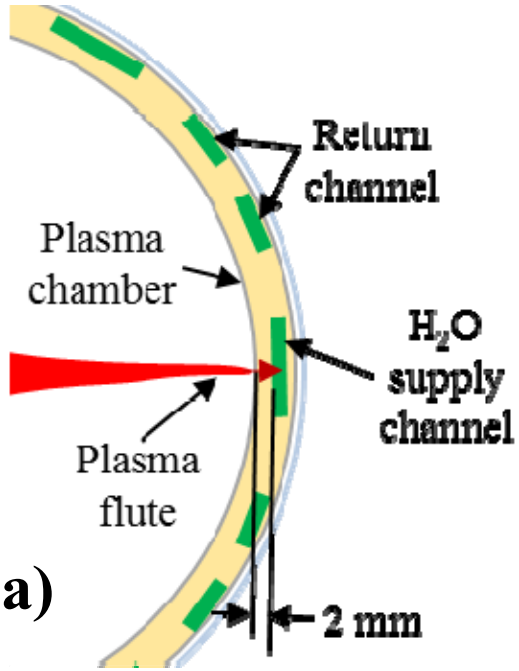

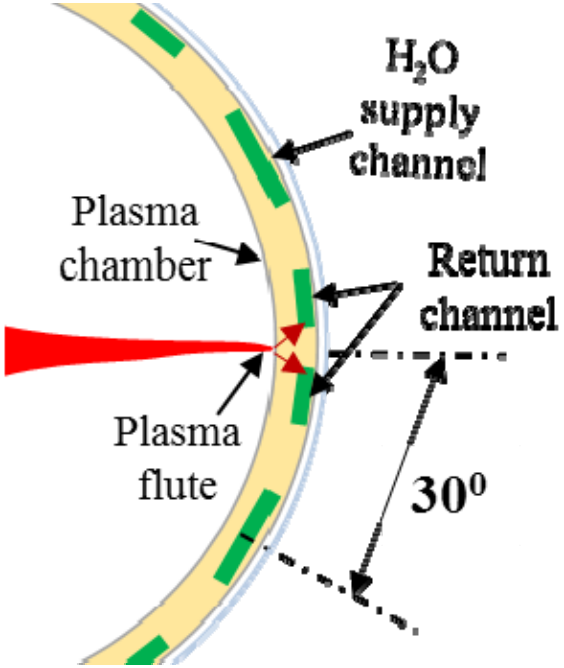

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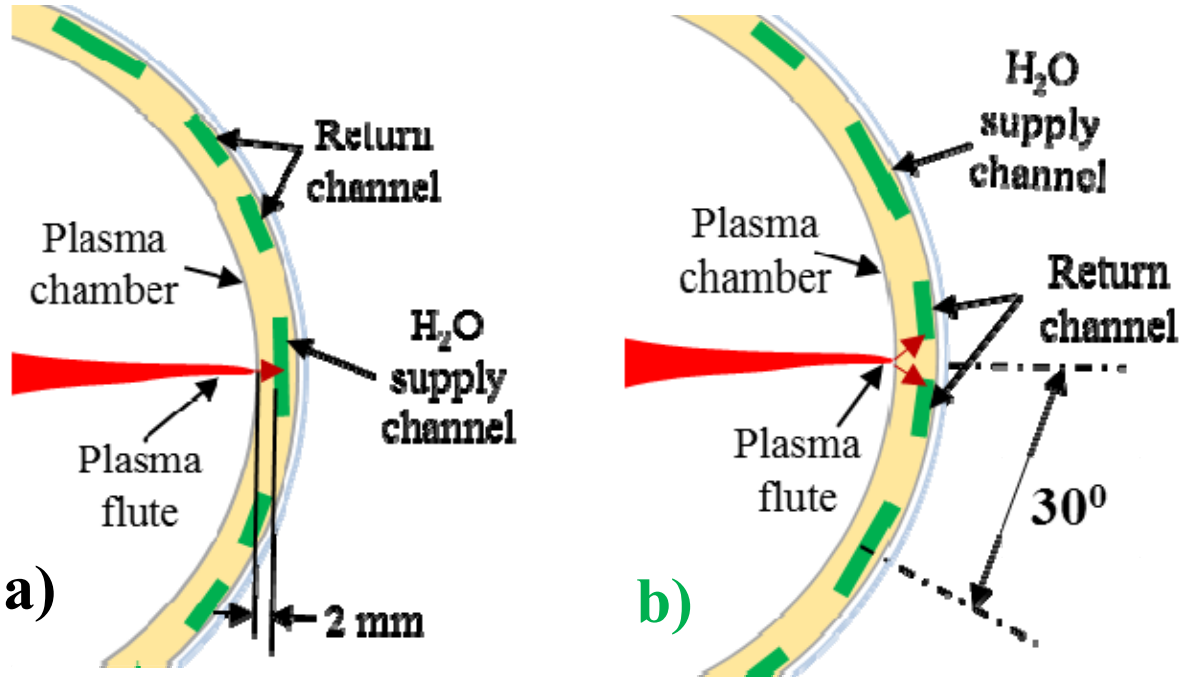

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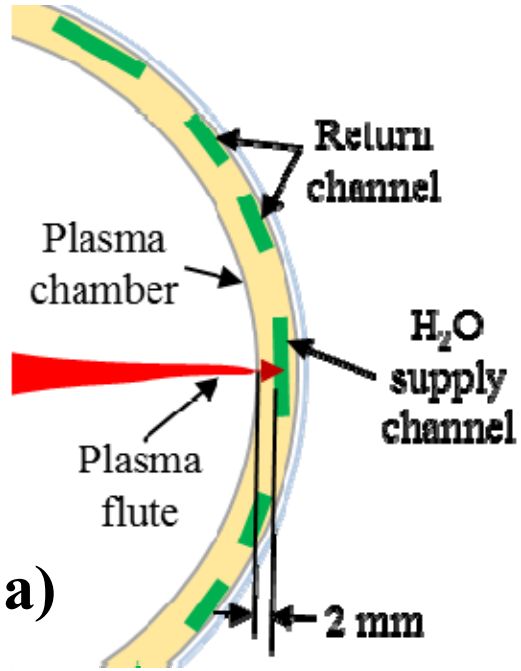

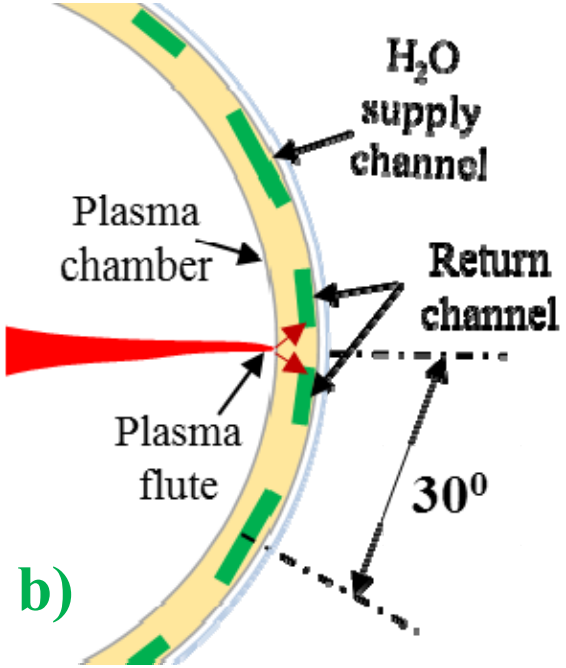

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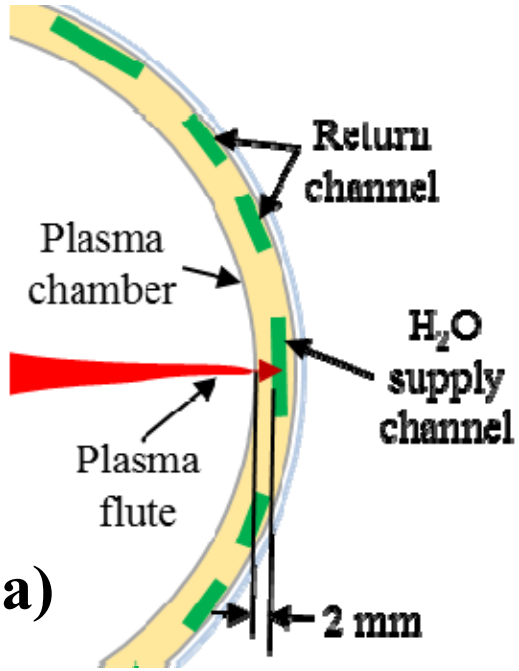

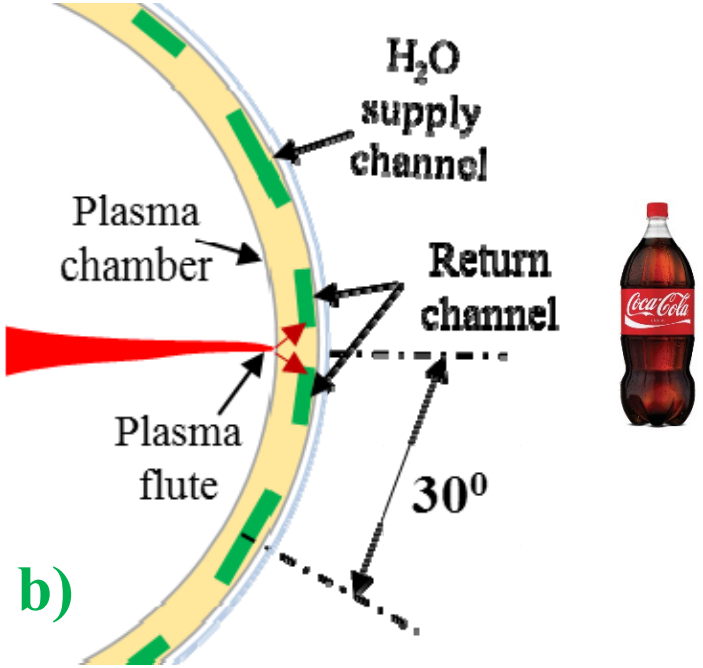

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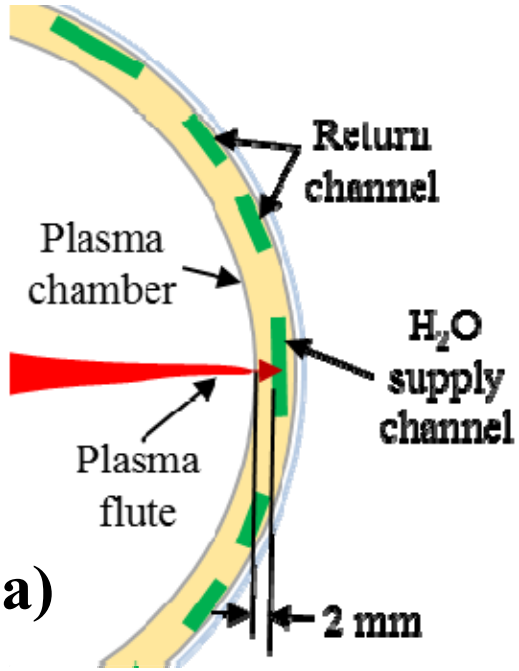

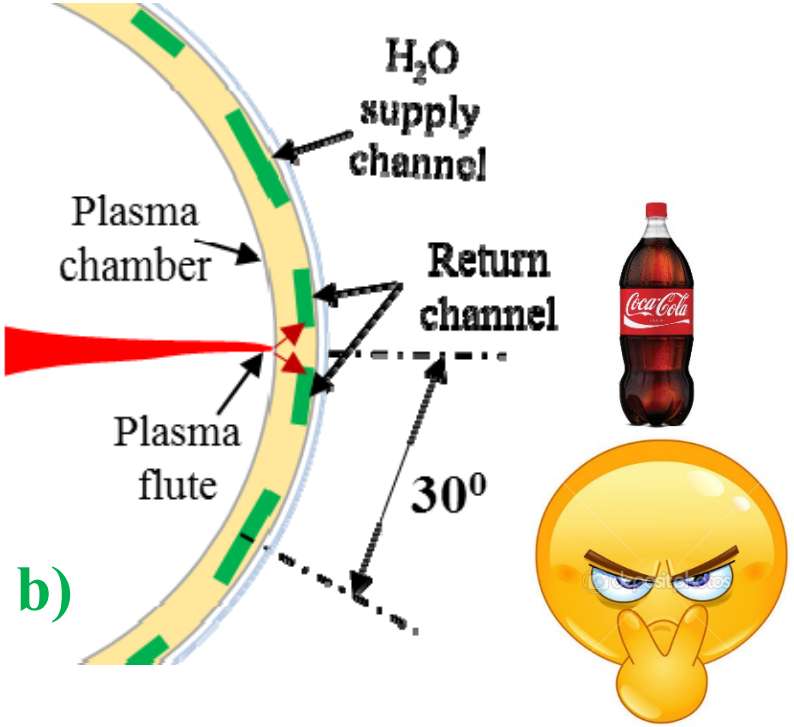

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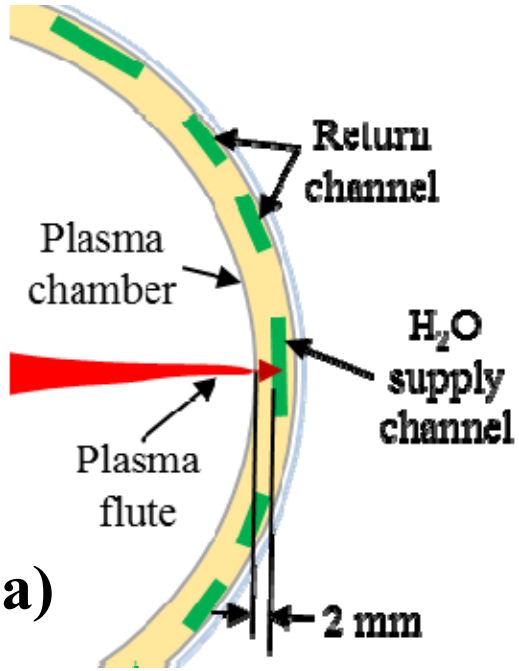

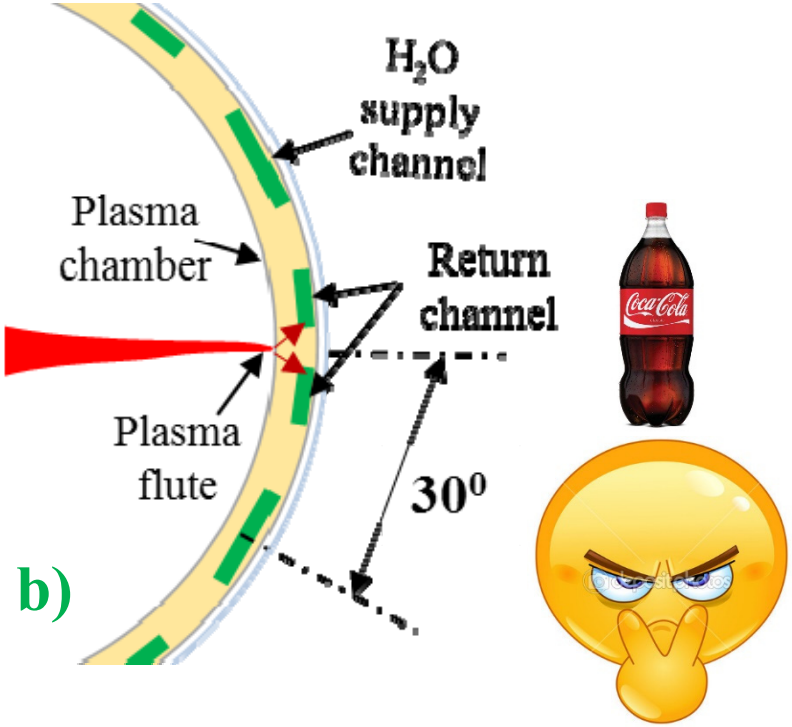

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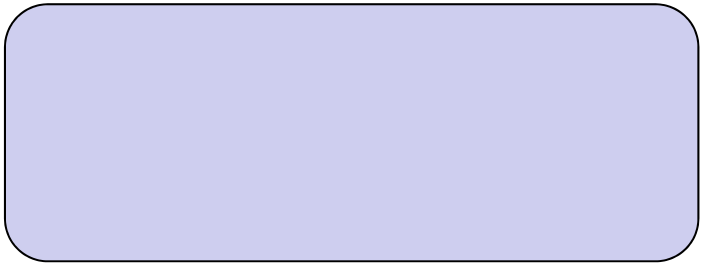

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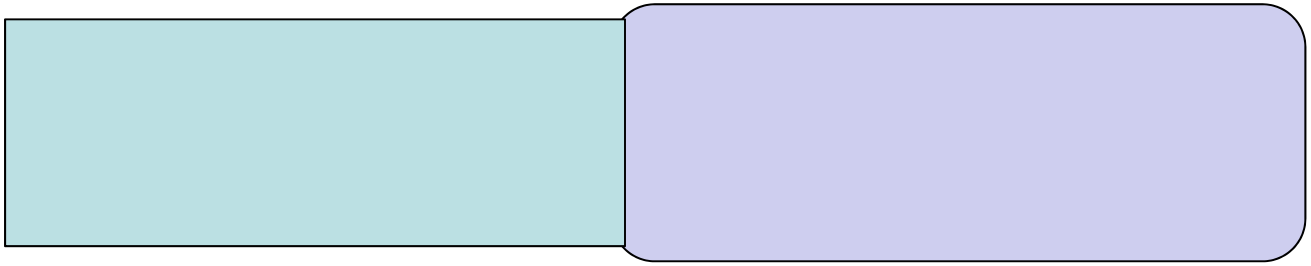

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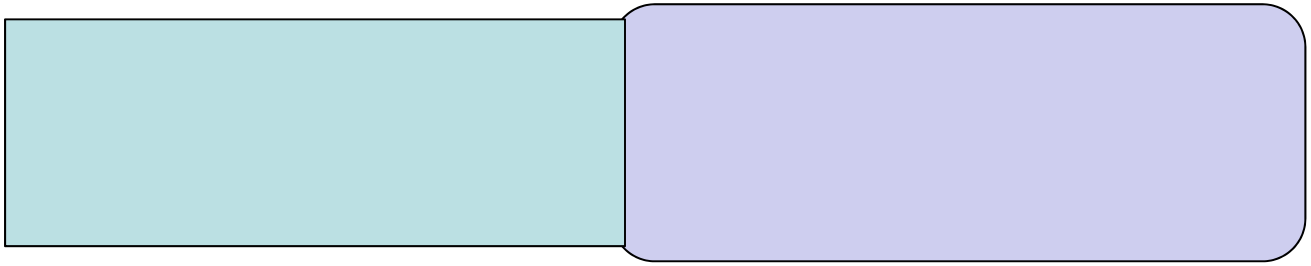

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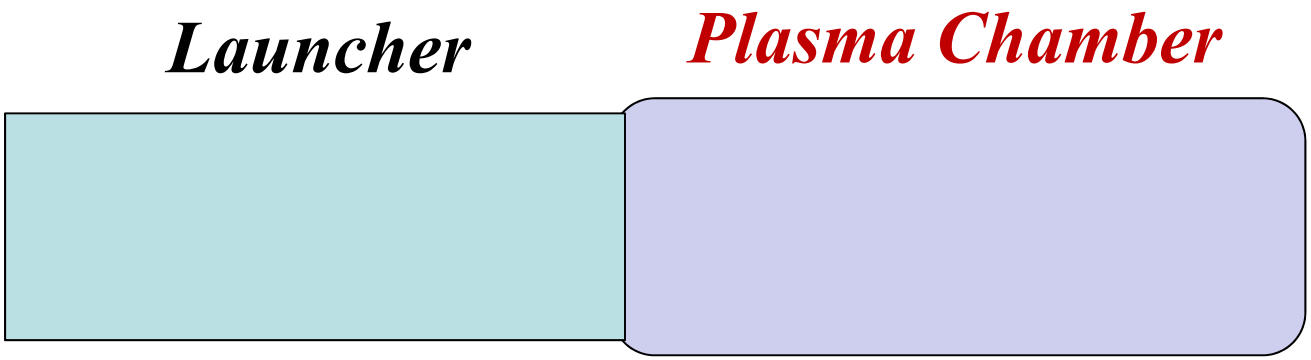

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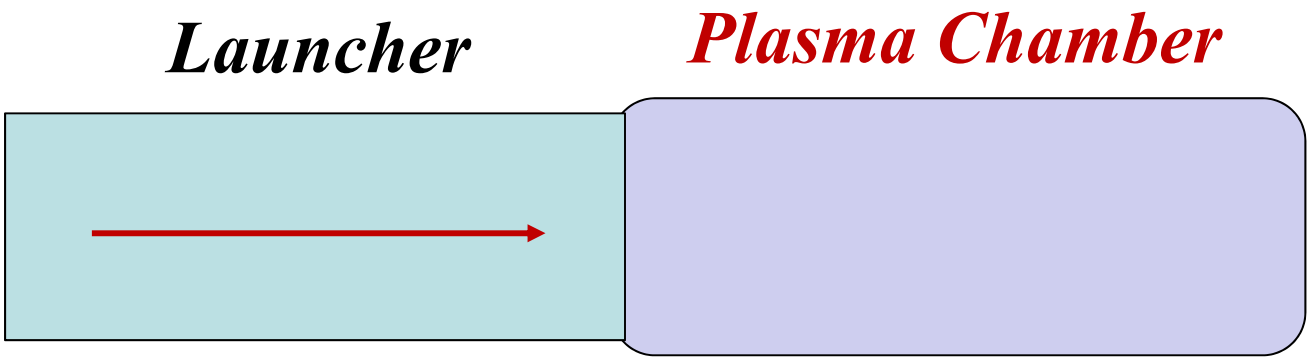

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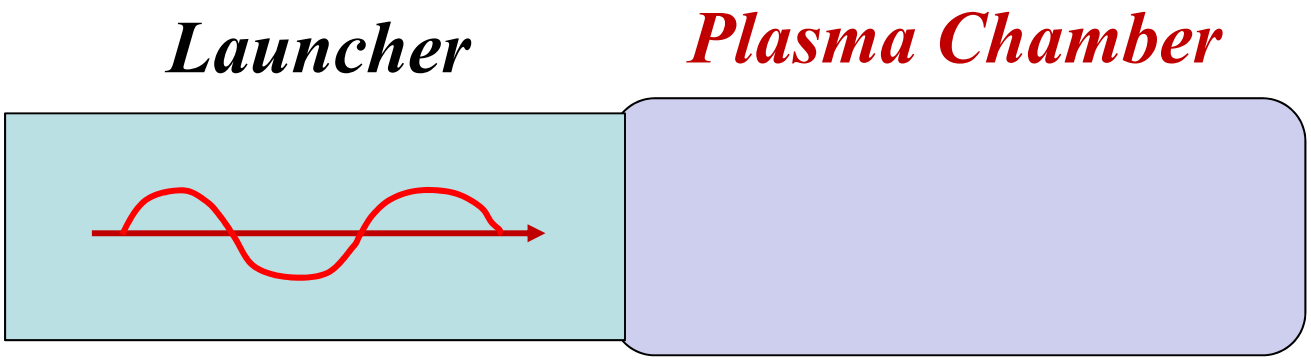

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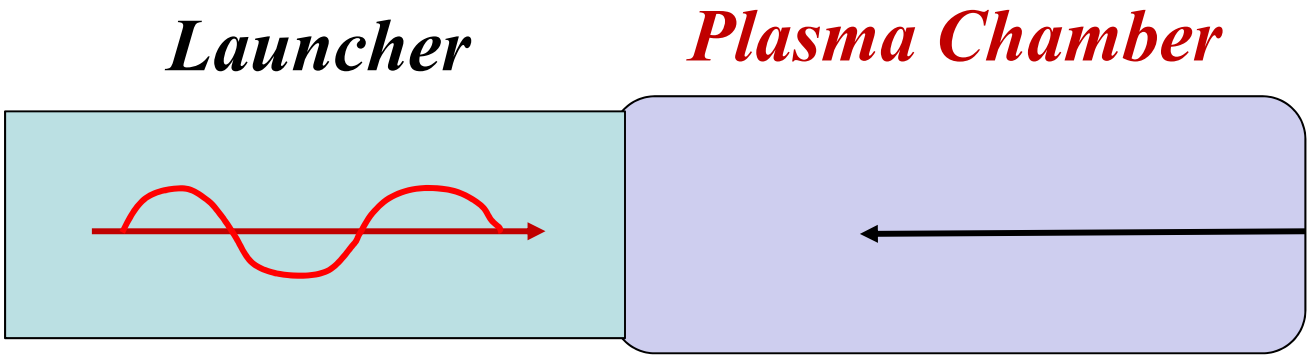

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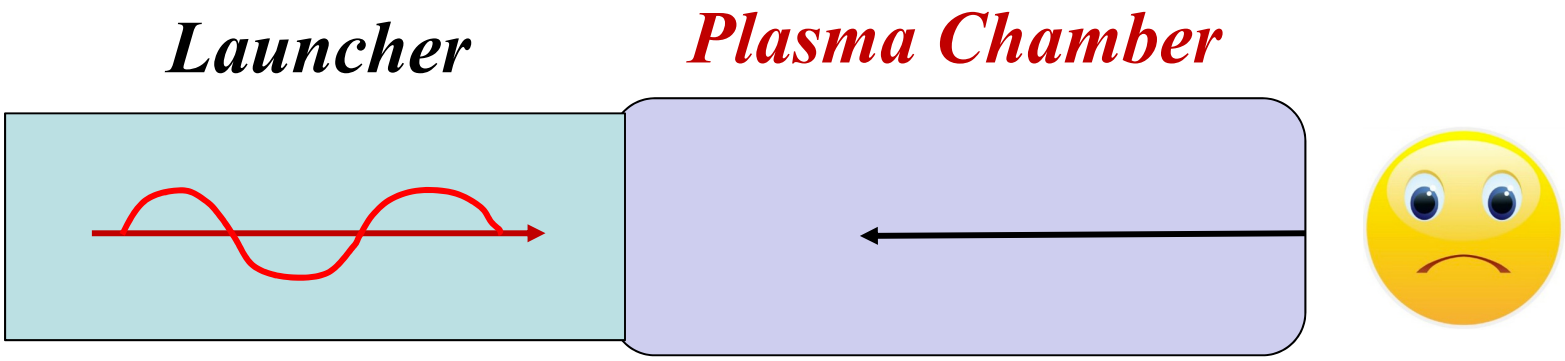

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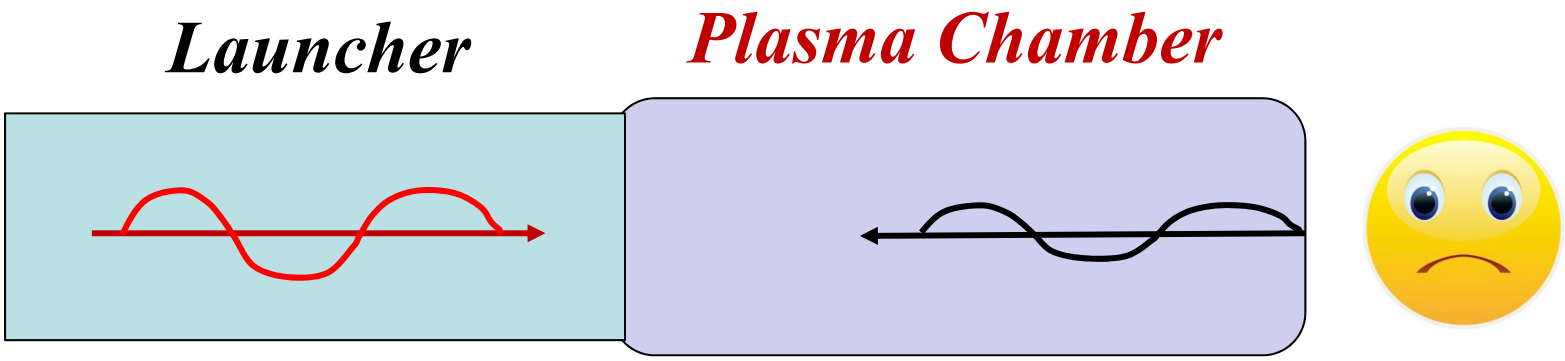

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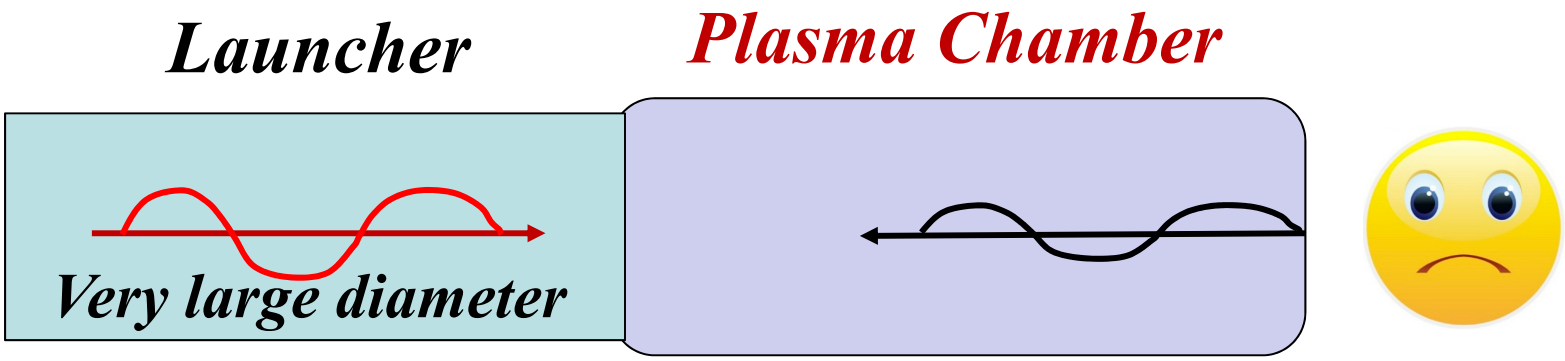

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Launcher **Plasma Chamber**

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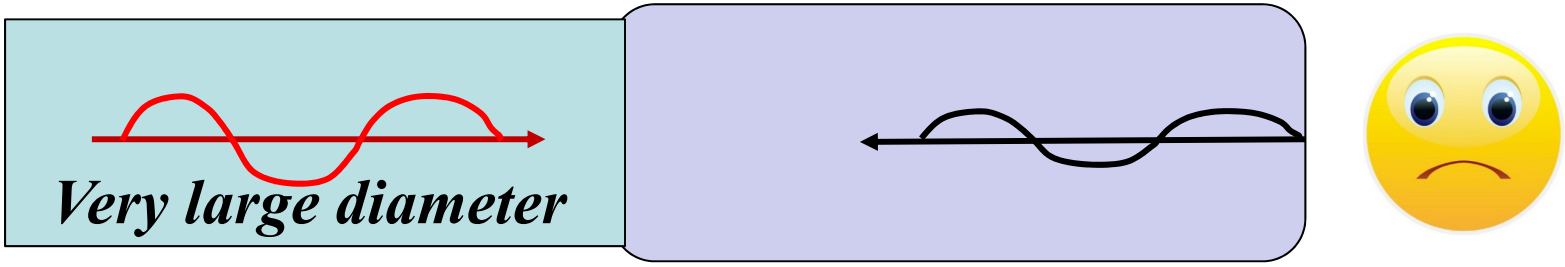

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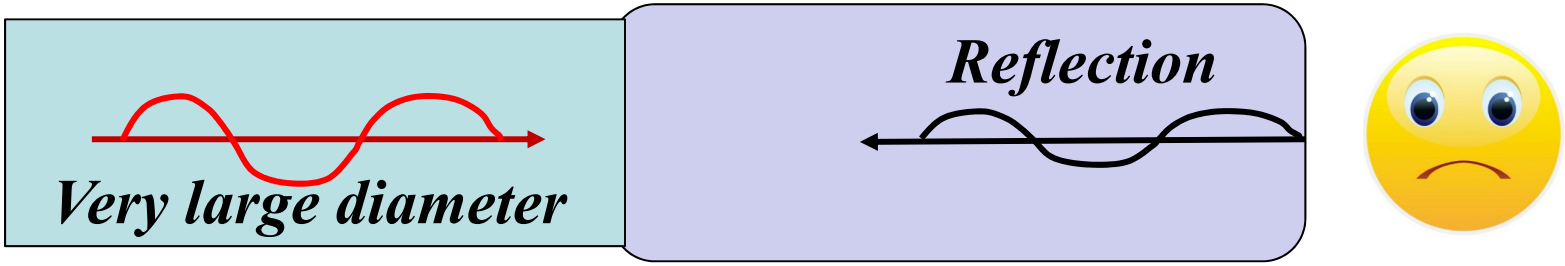

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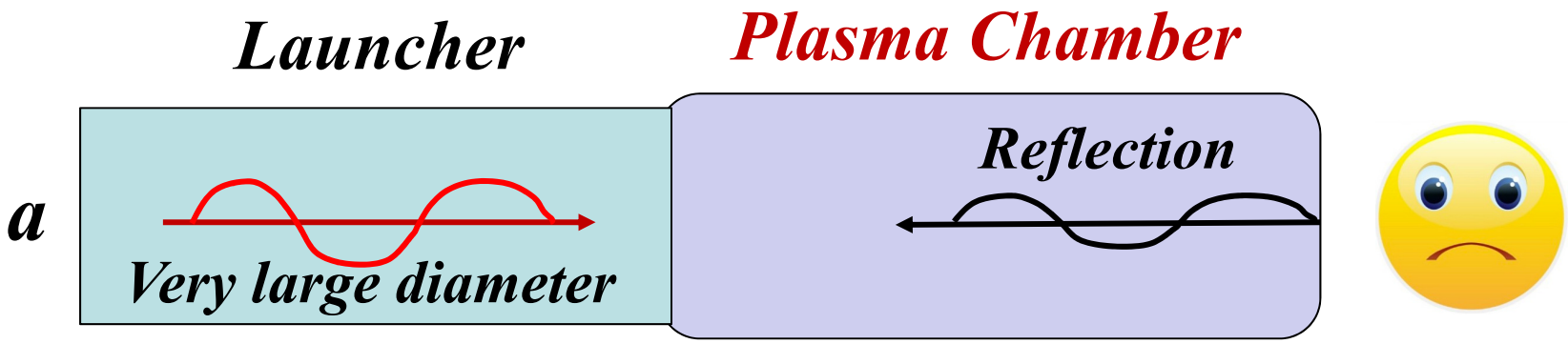

Very small diameter

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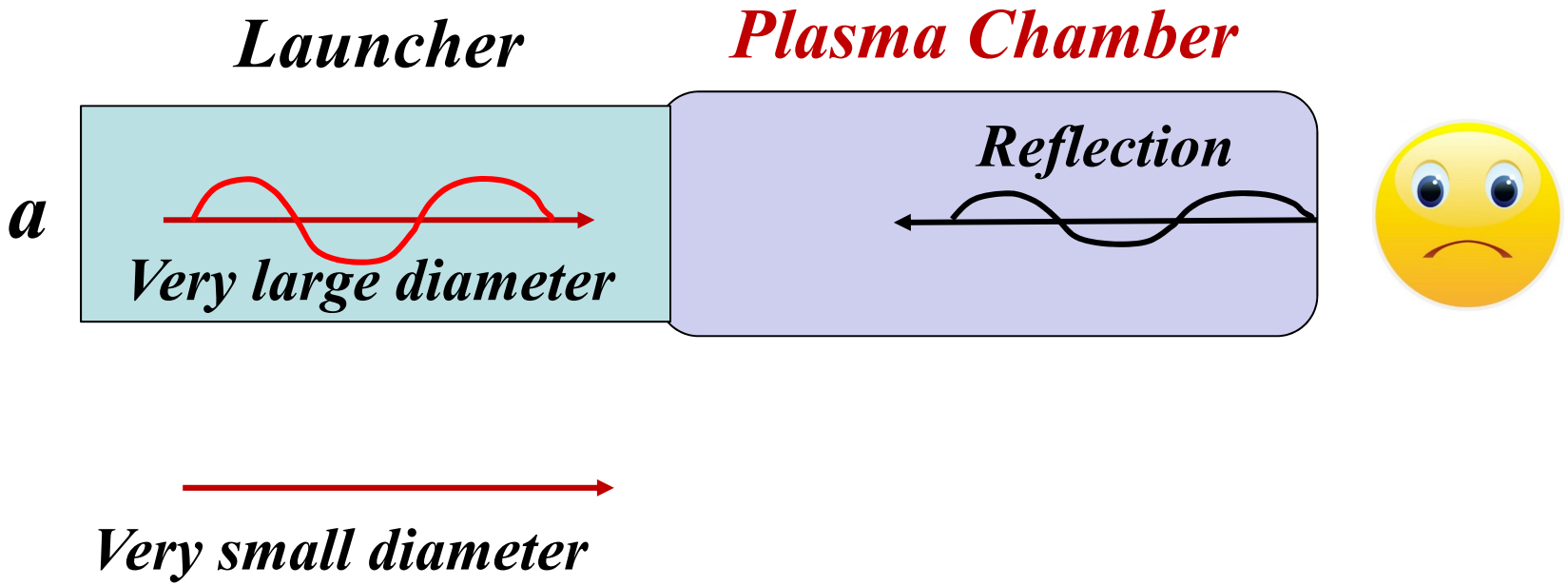

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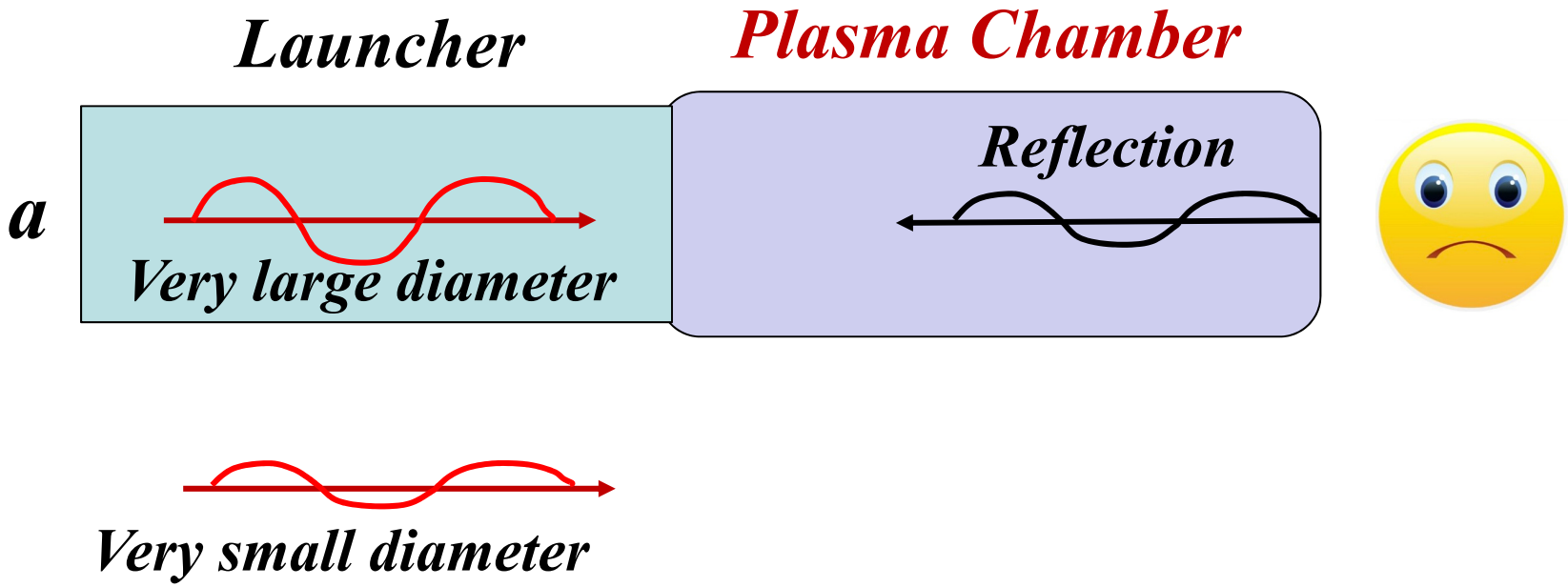

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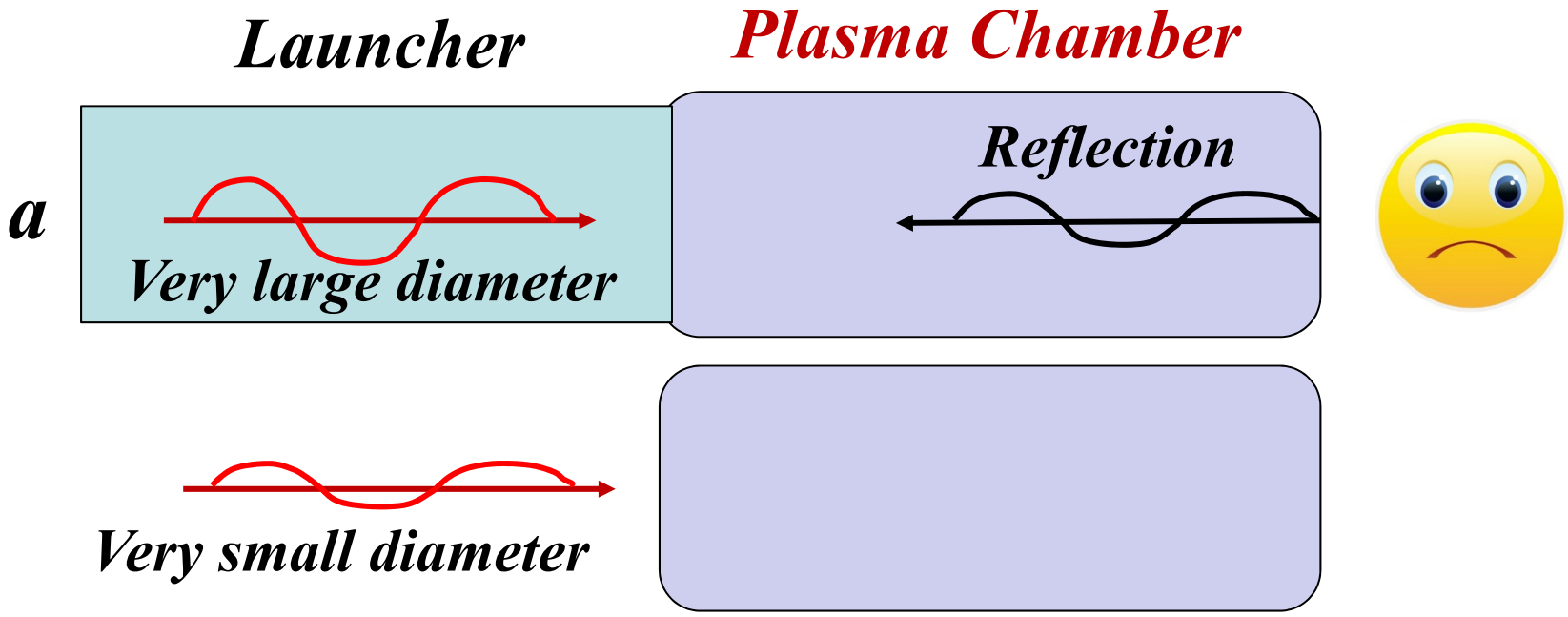

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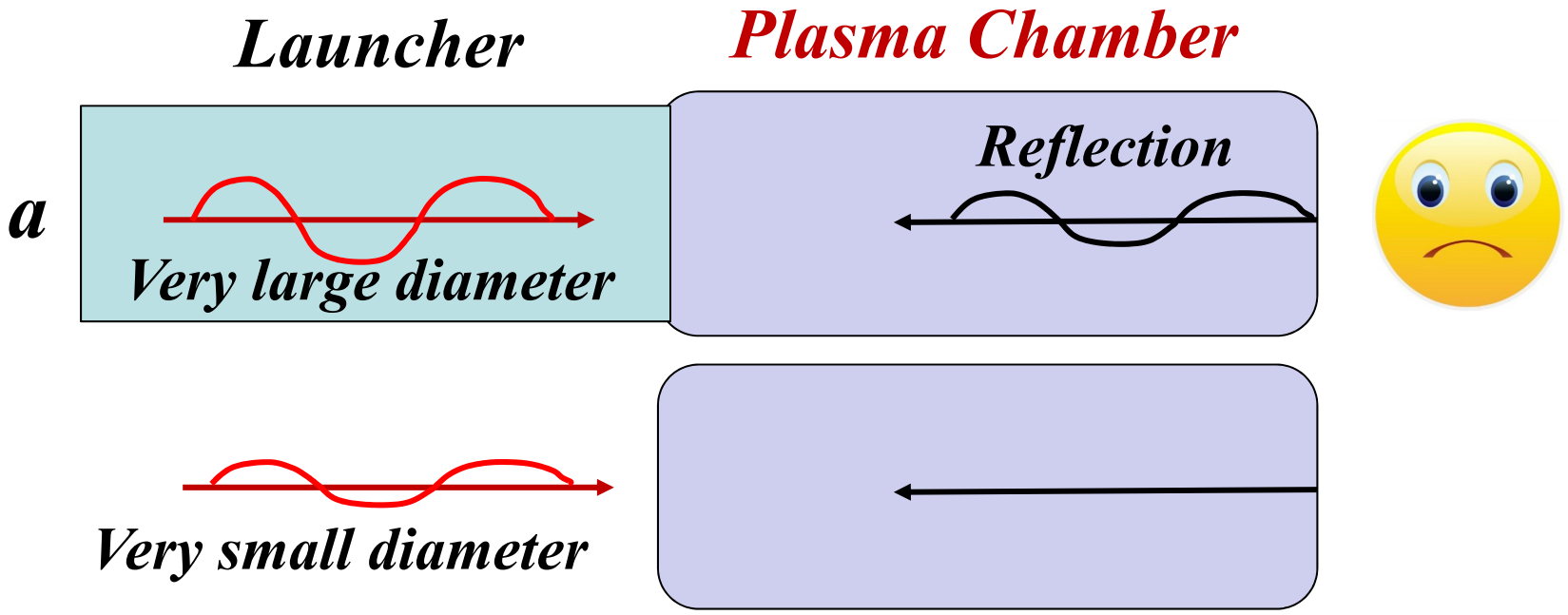

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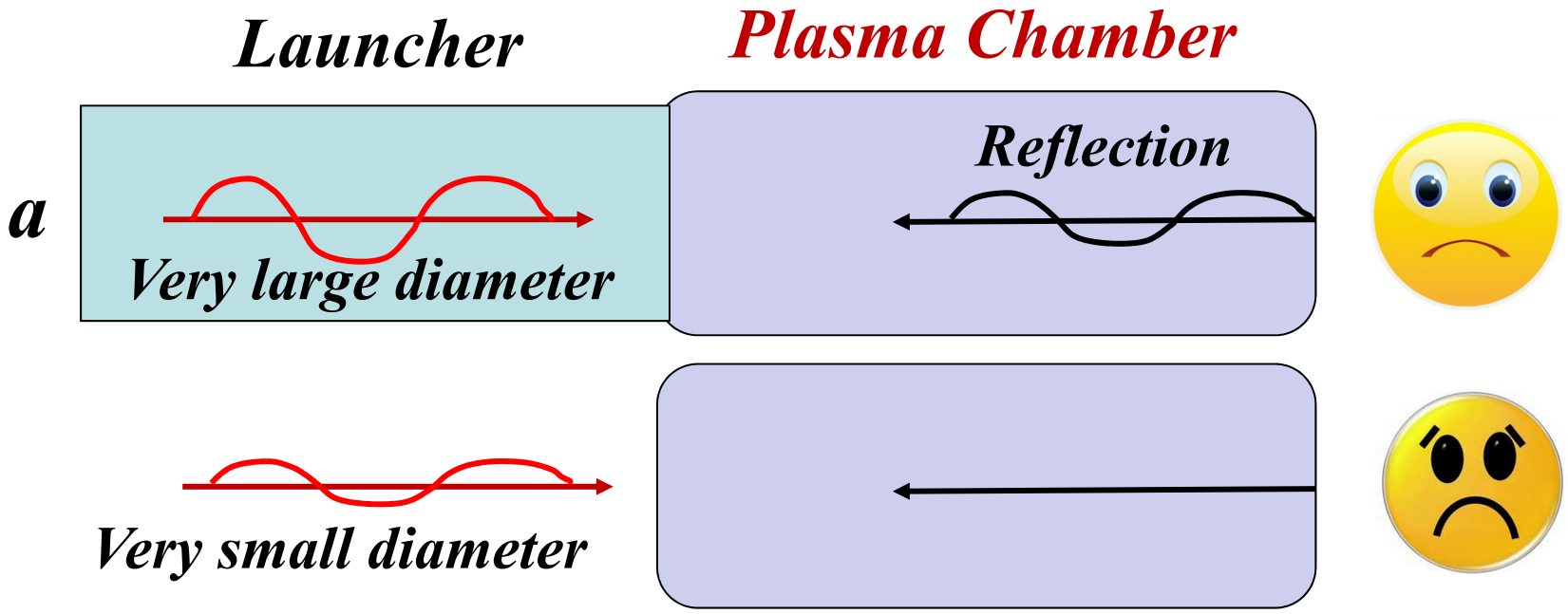

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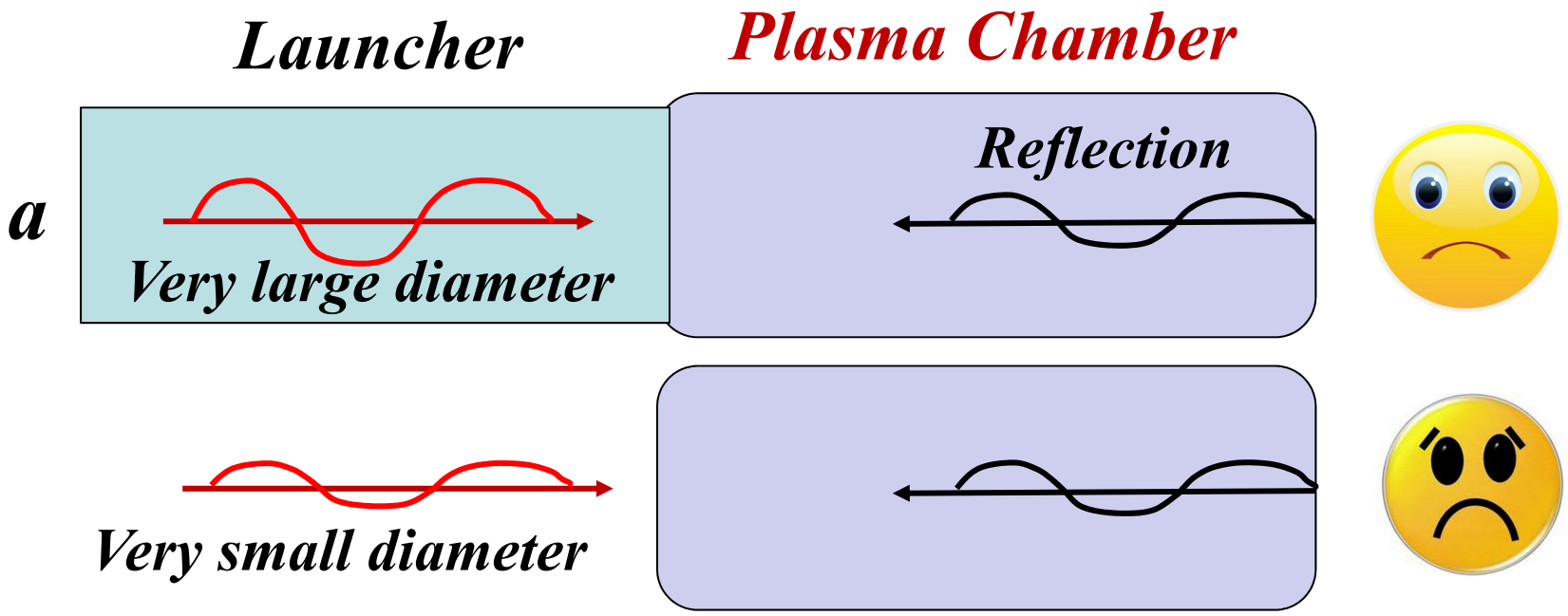

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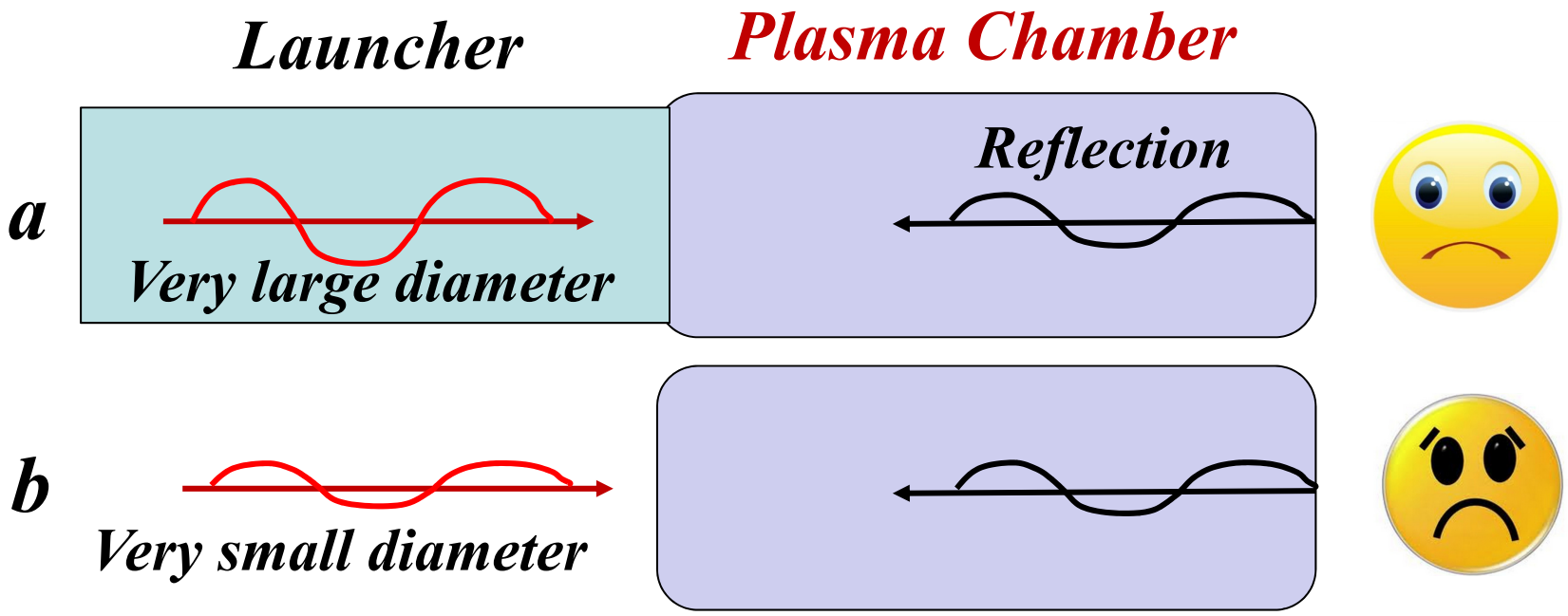

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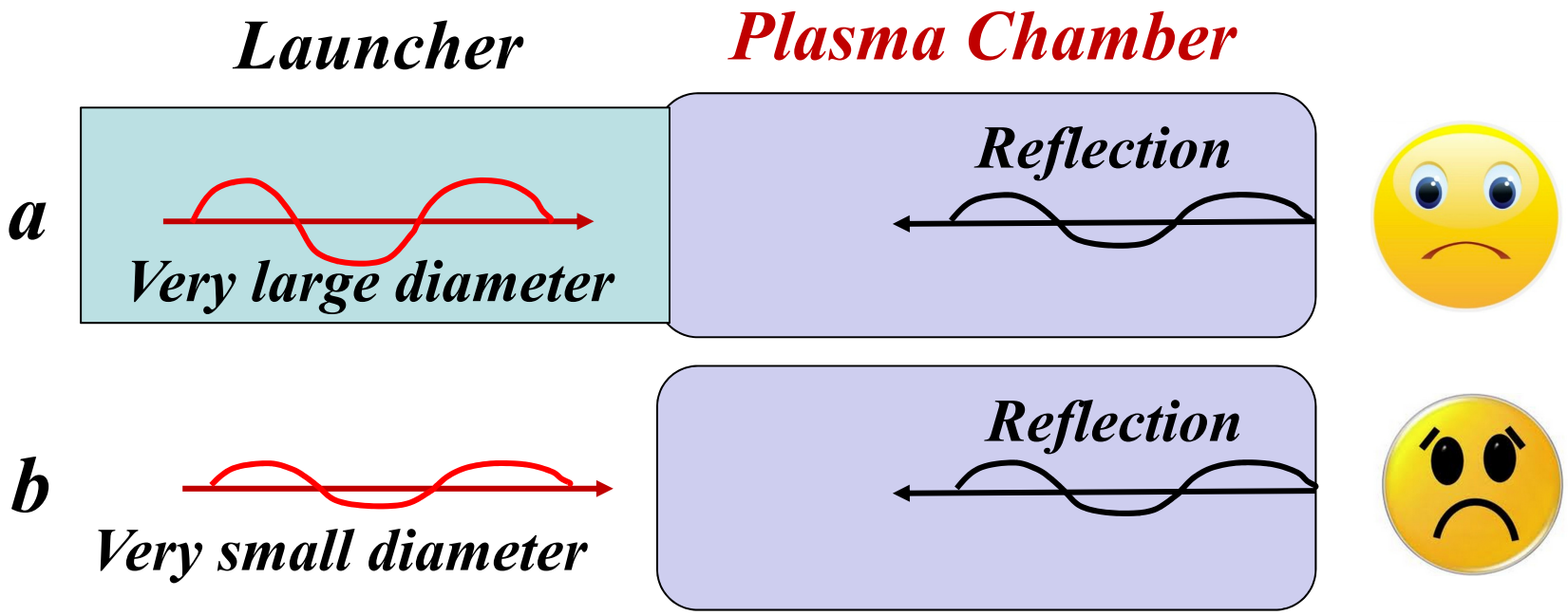

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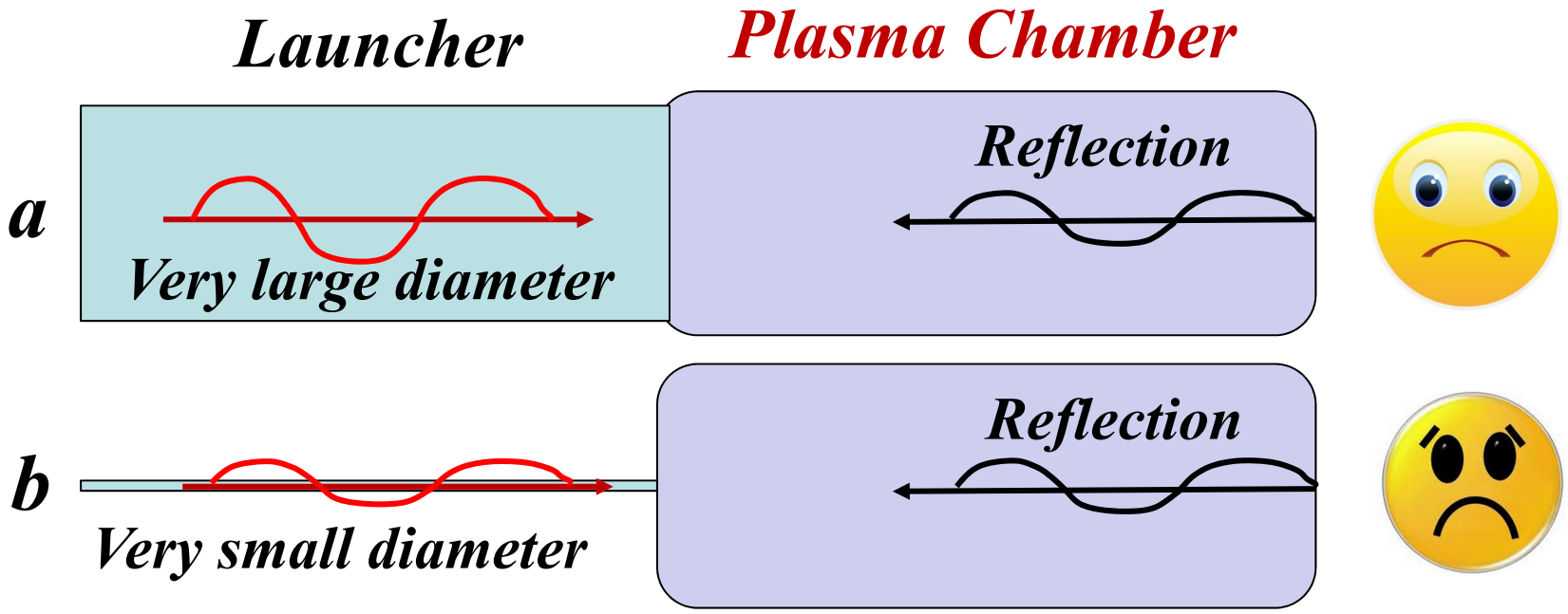

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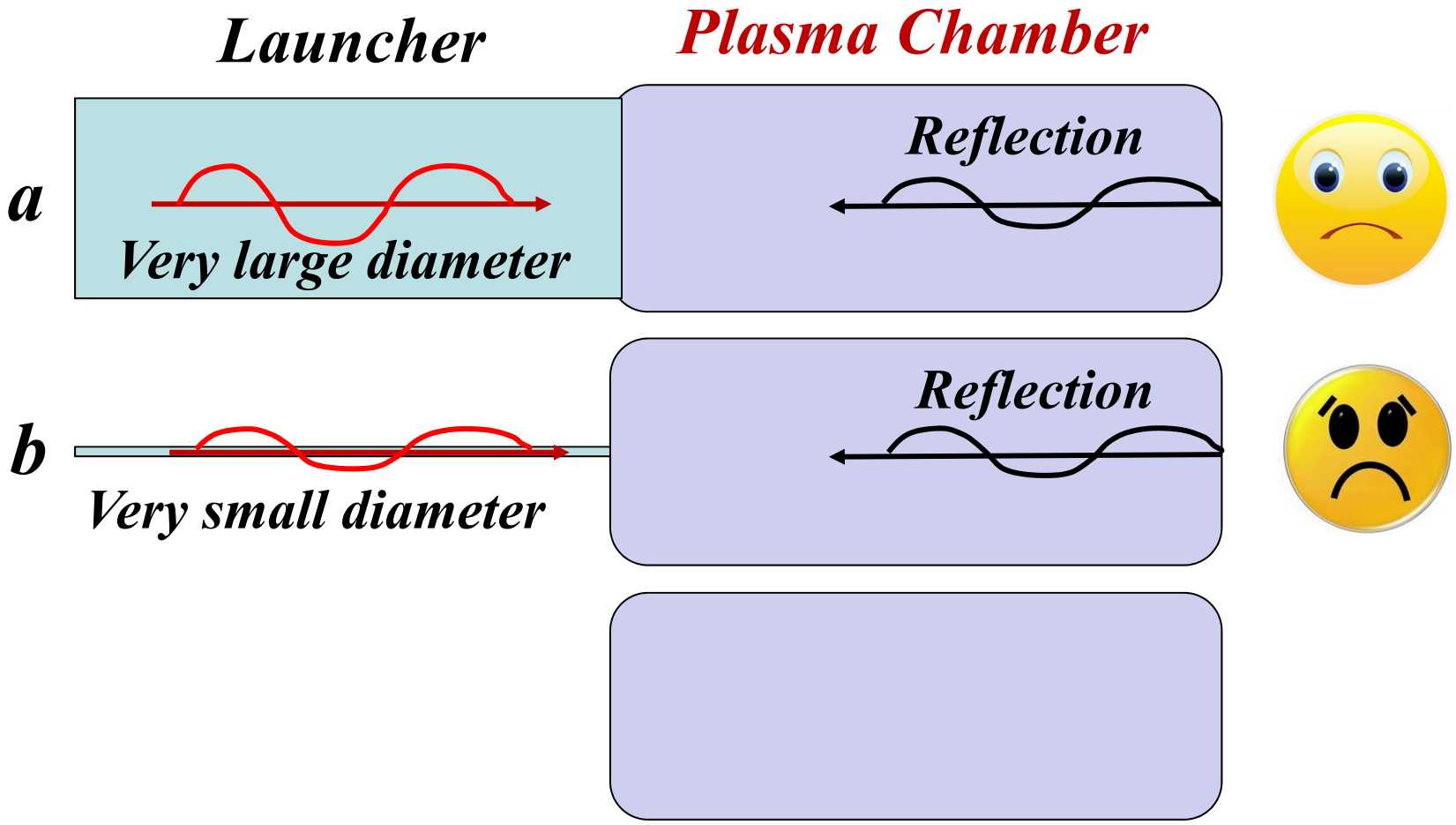

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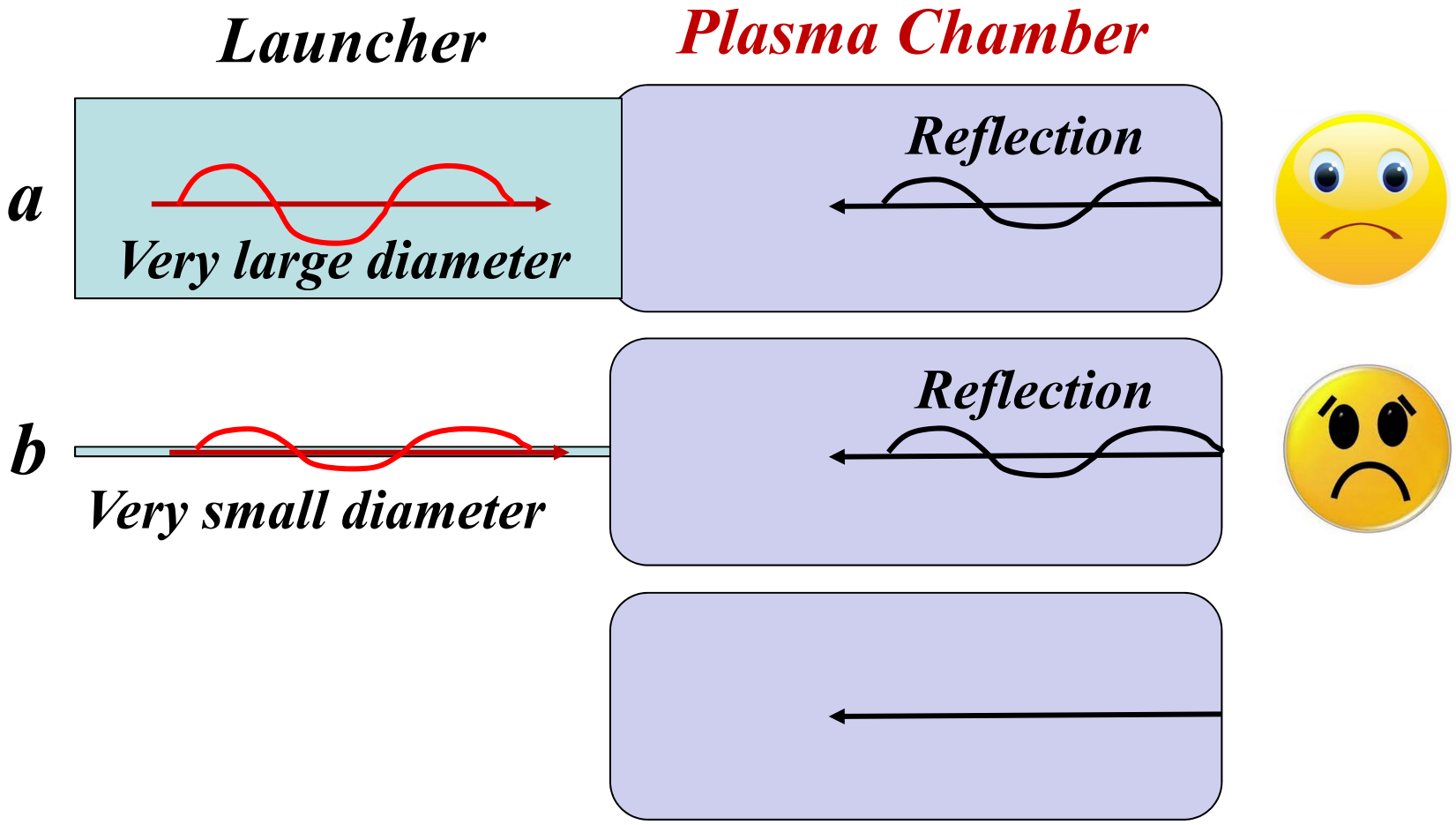

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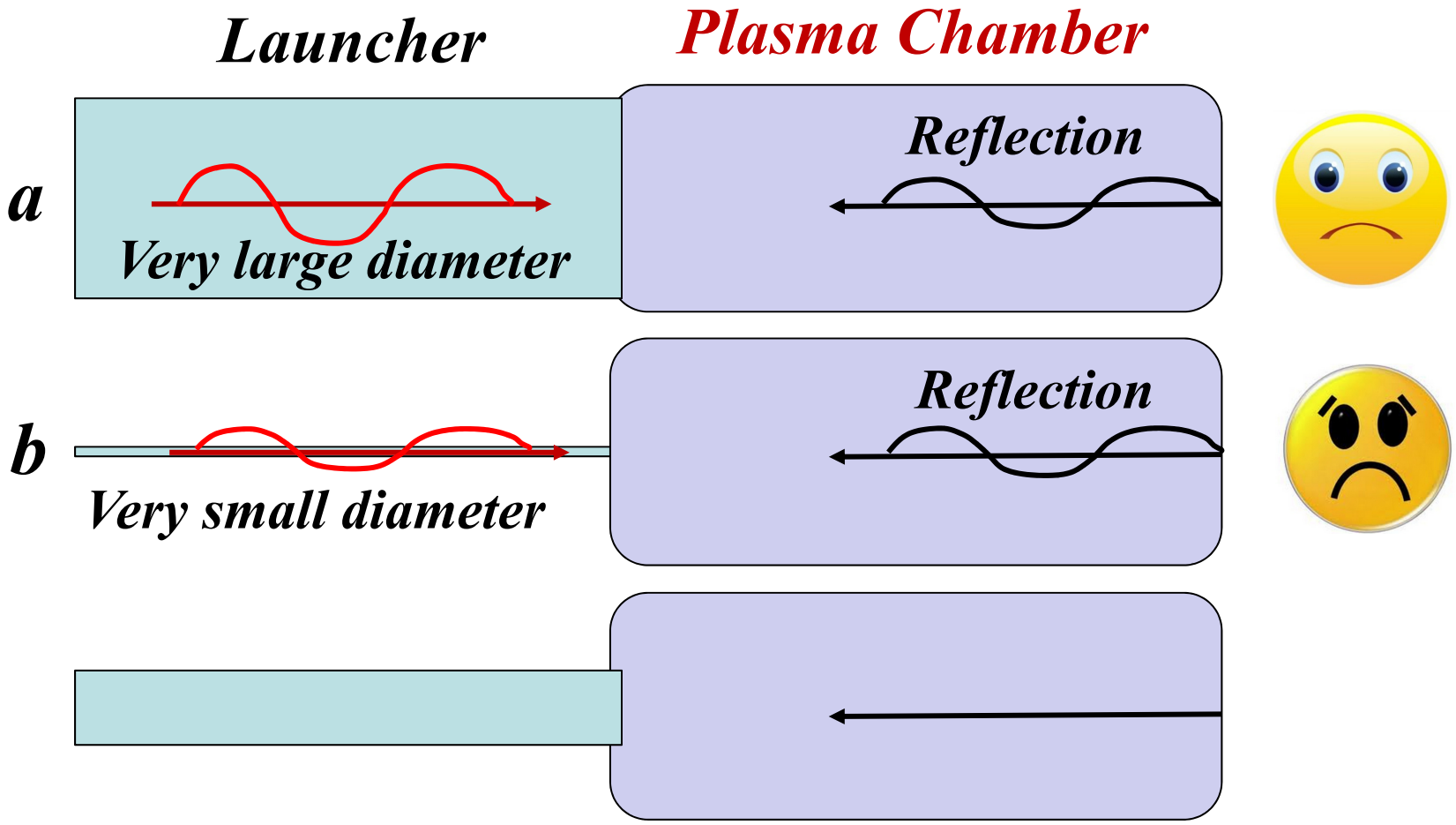

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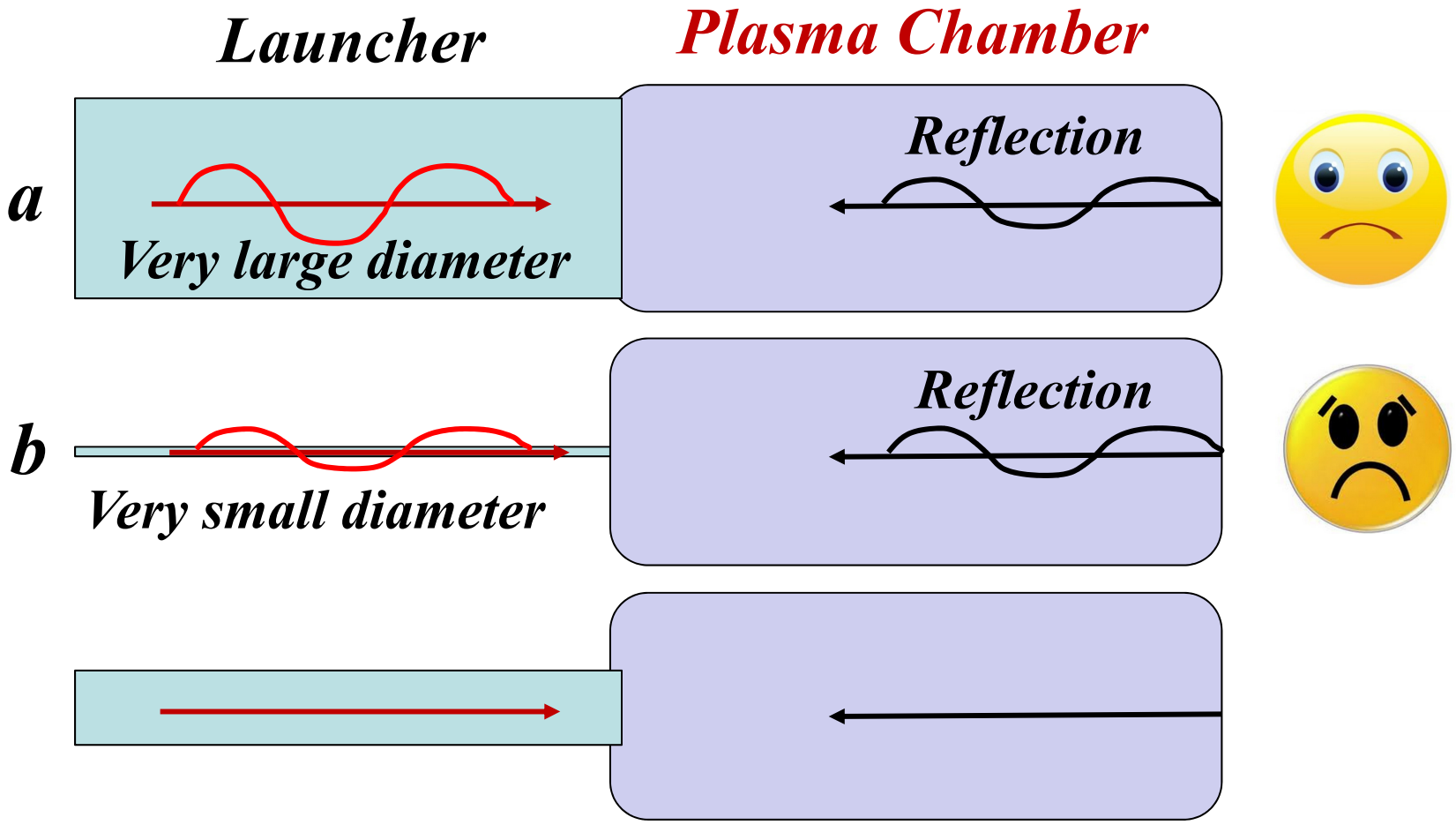

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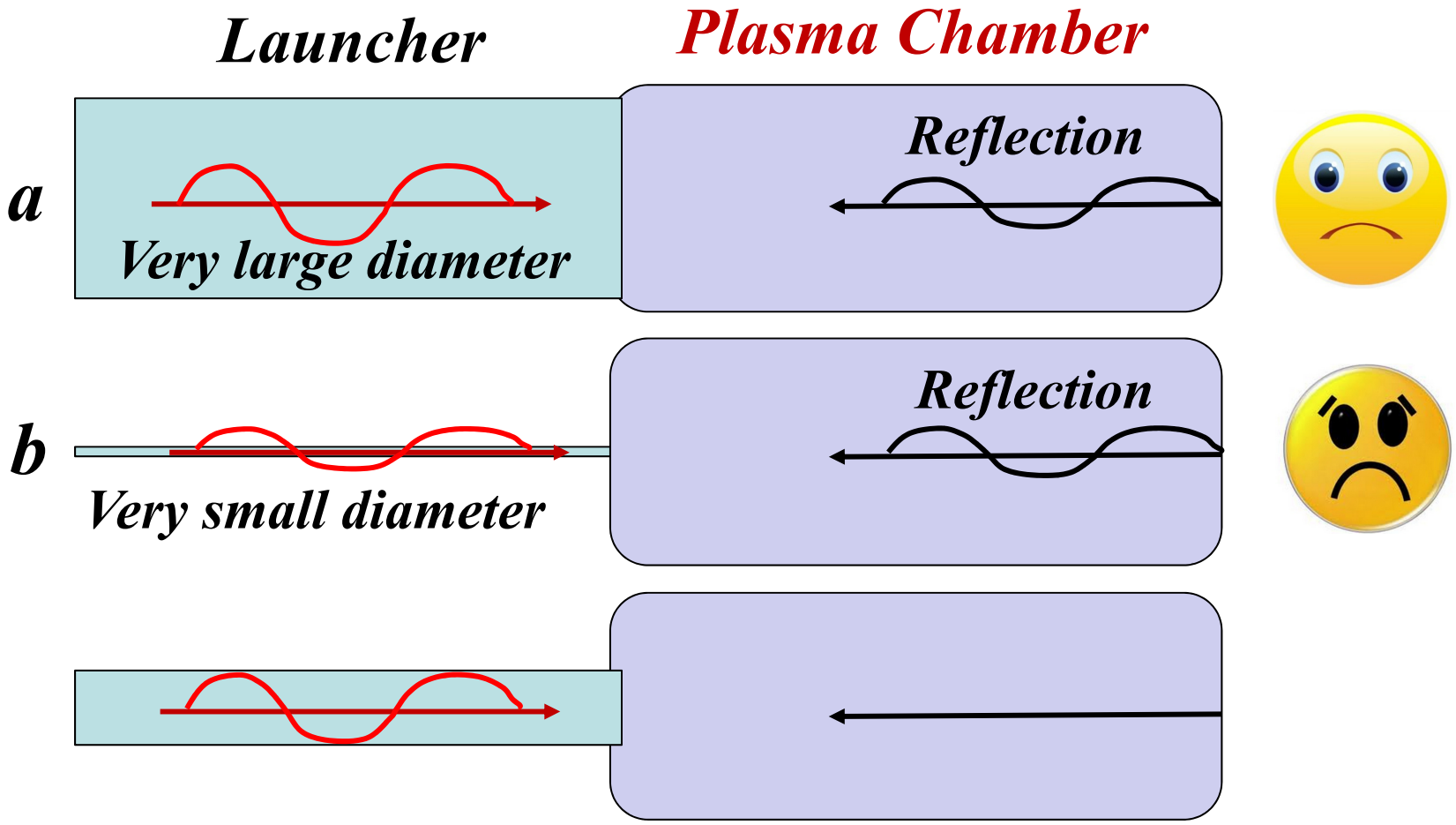

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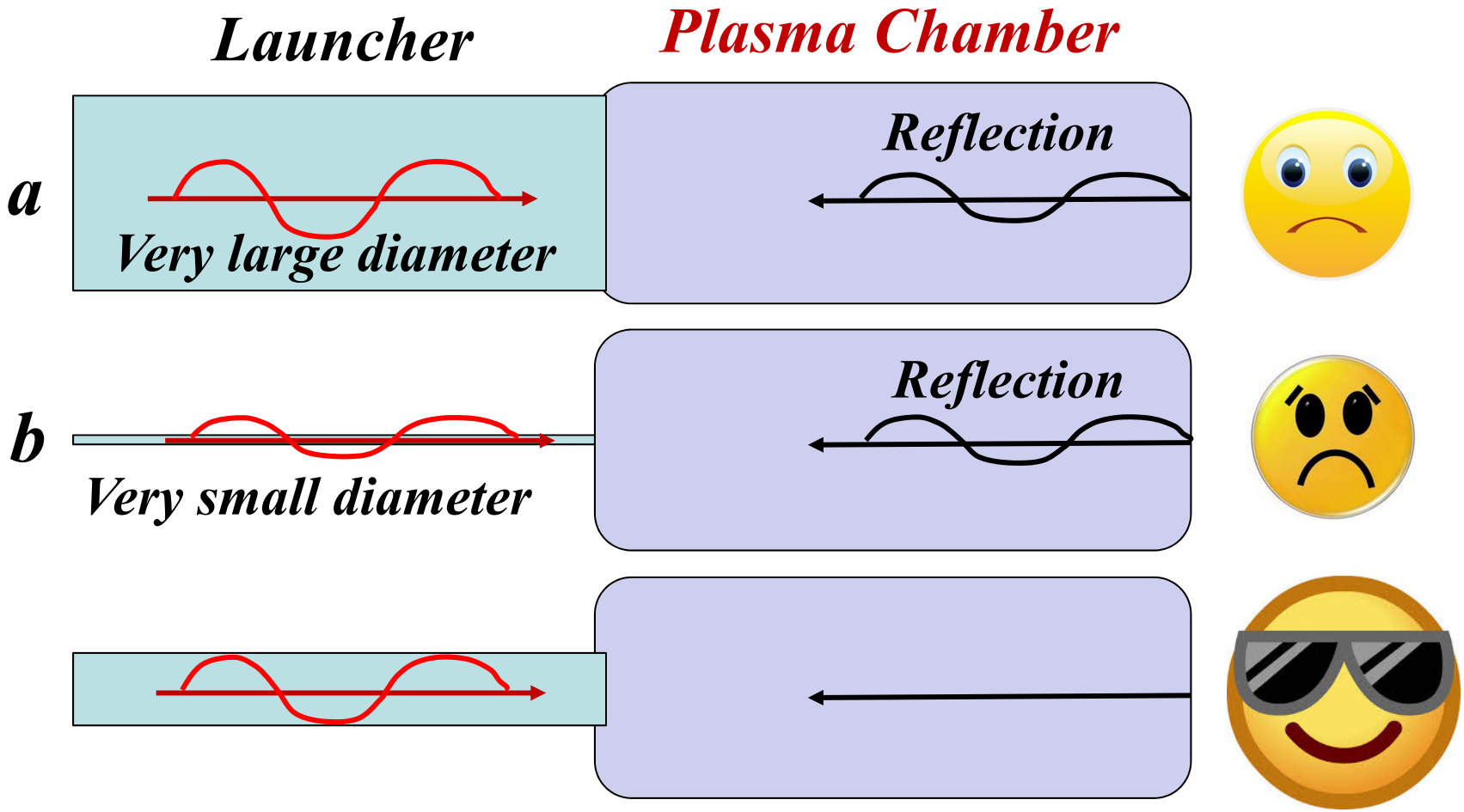

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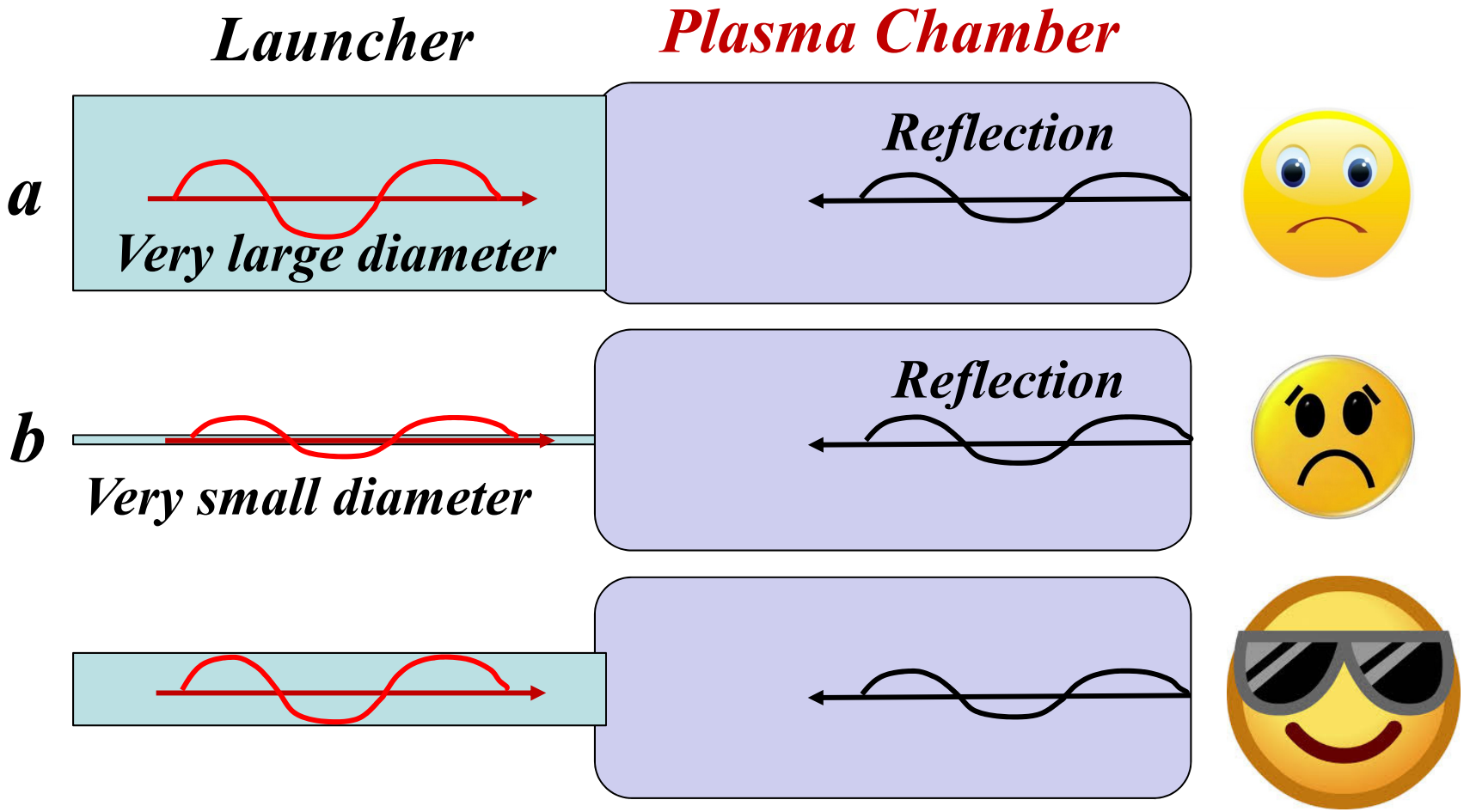

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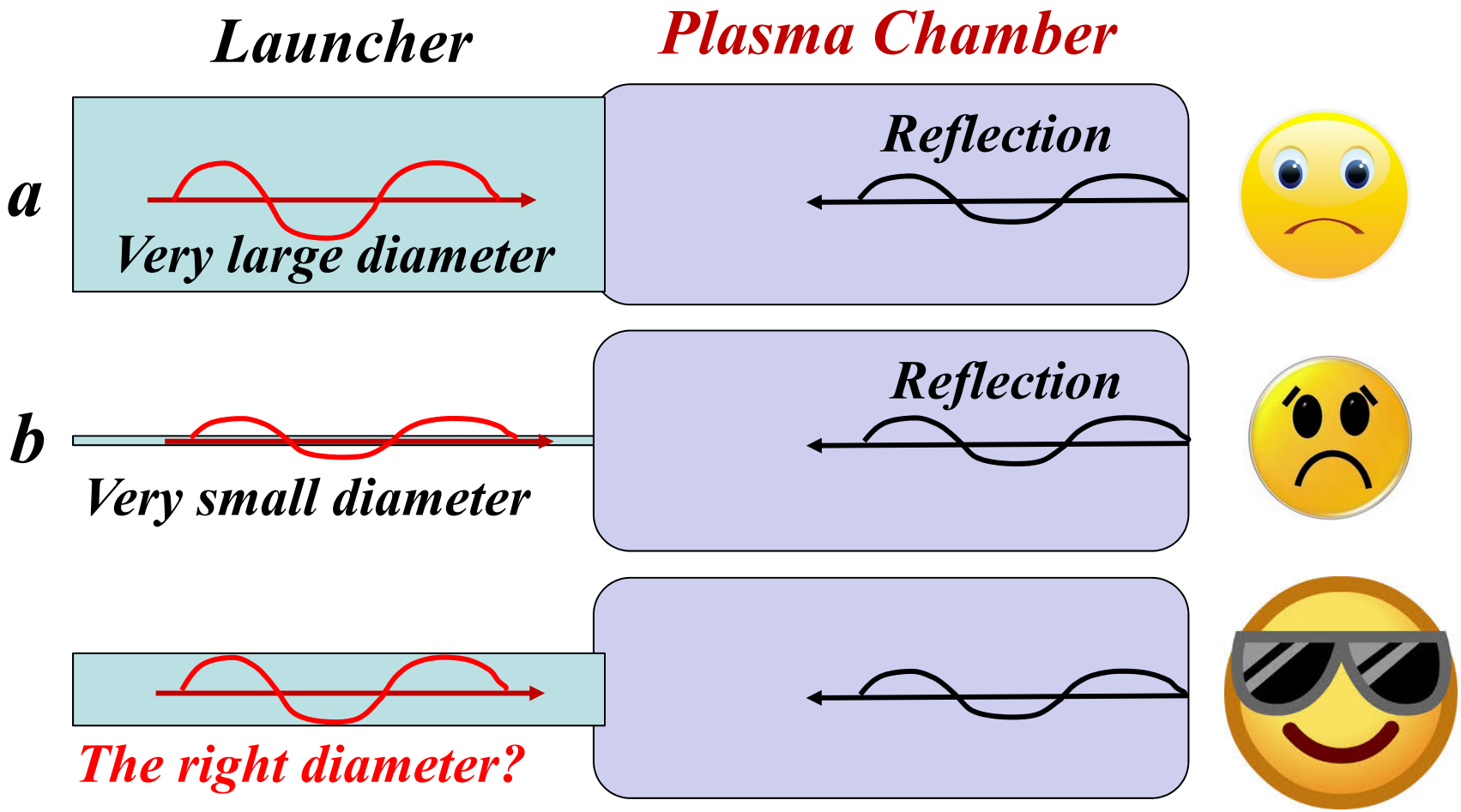

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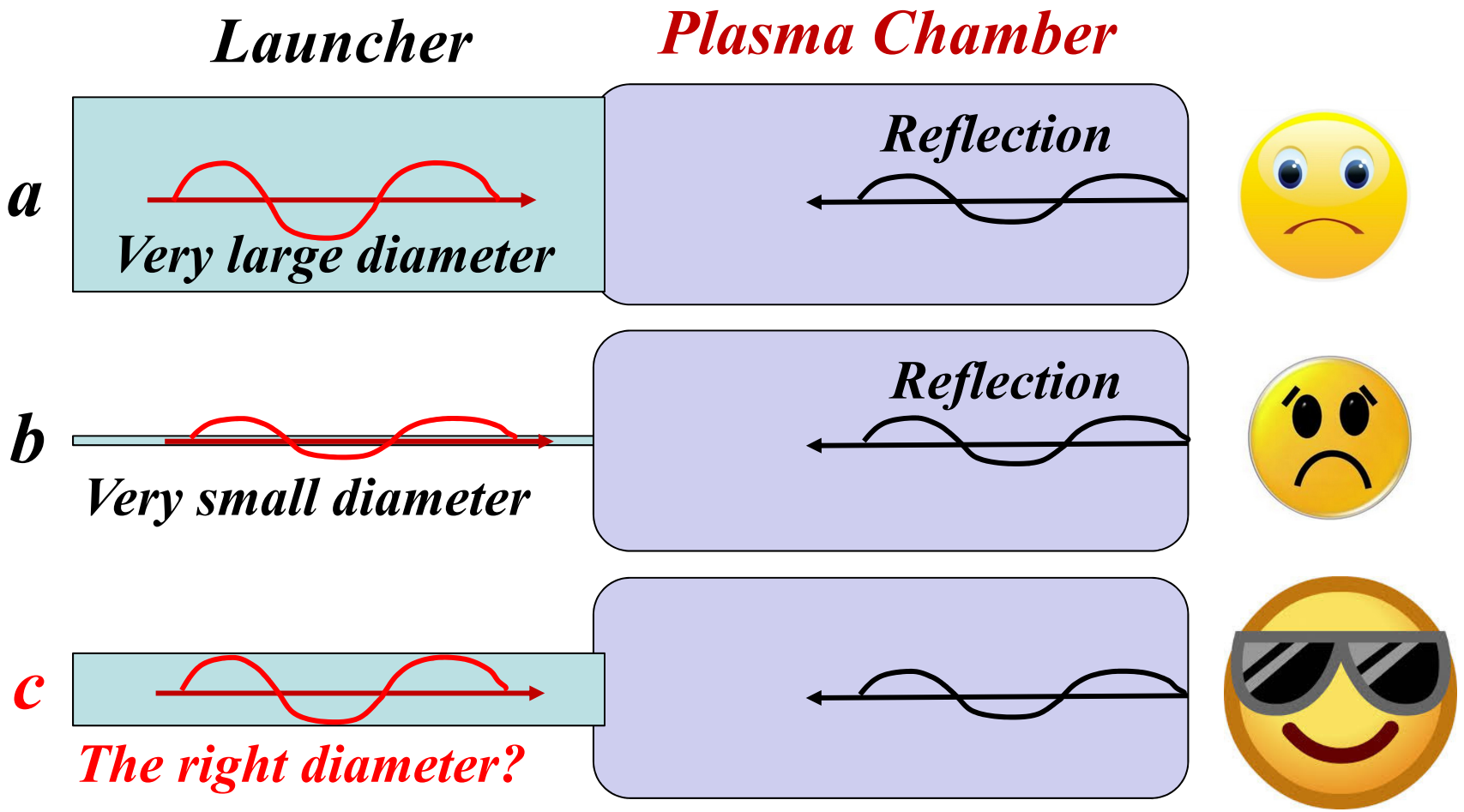

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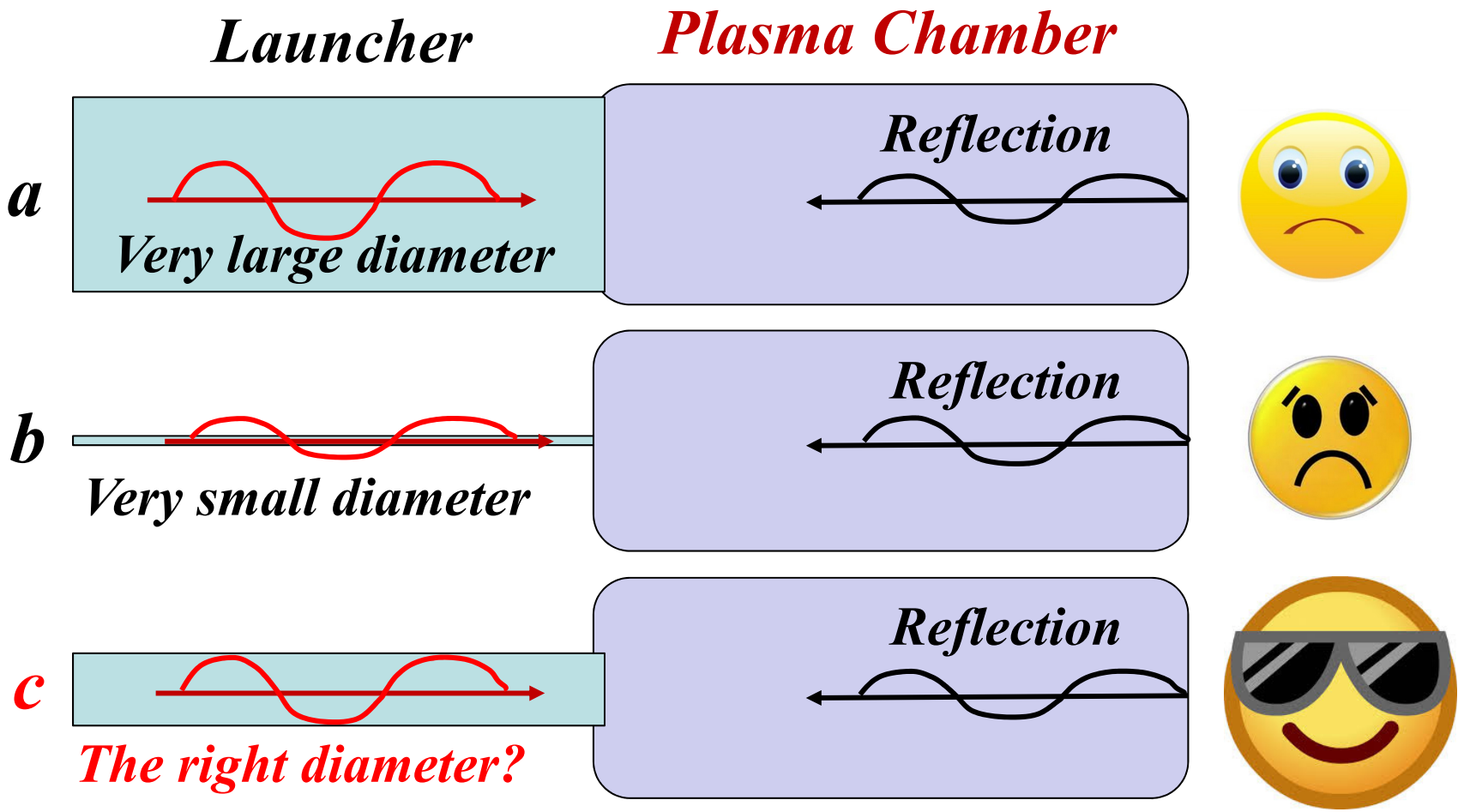

Remedy 3

SERSE: The 1st ECRIS to successfully couple 28 GHz with circular waveguide of over size Ø30-32 mm

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TE_{01} straight waveguide

Ø 31.8 mm

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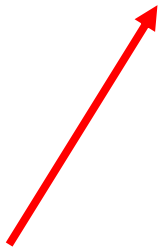

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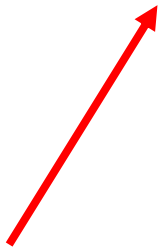

TE_{01} straight waveguide Ø 31.8 mm

TE_{01} taper transition exit Ø 20 mm

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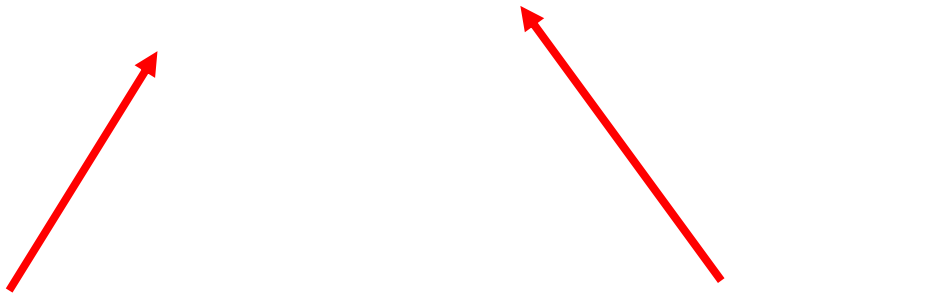

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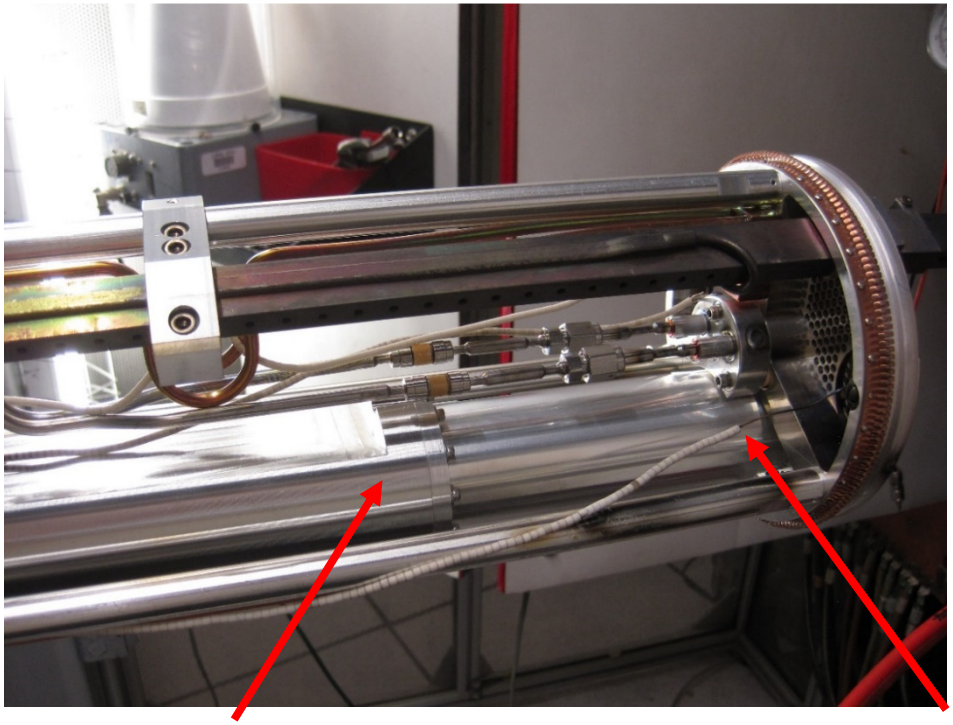

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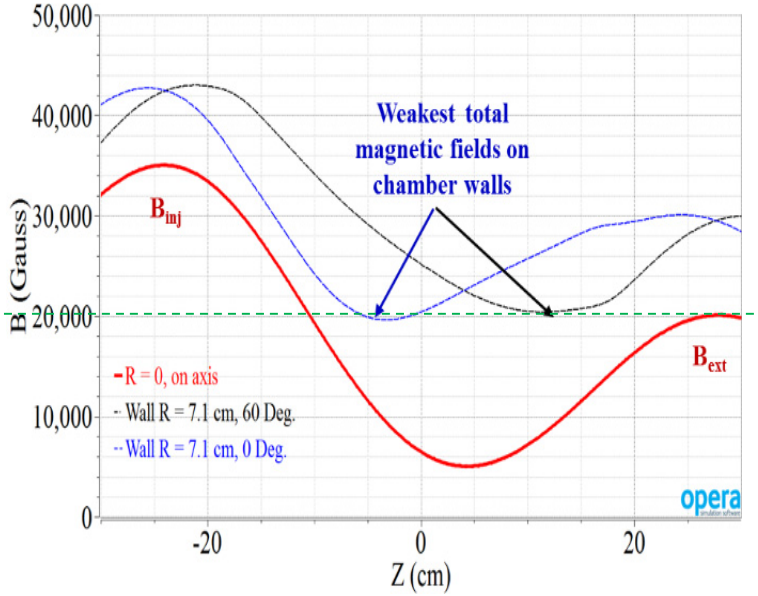
Remedy 4

Magnetic Field Configurations



+.....

Present

Lower B_{ext} and B_{min}

Remedy 4

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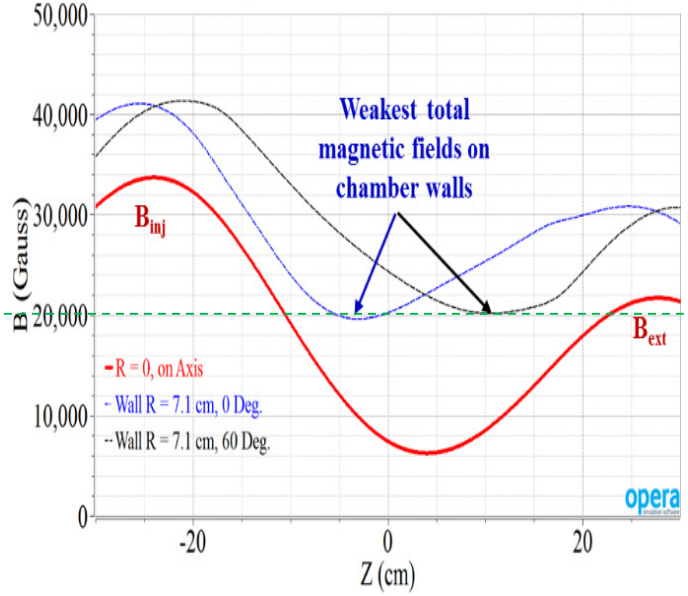

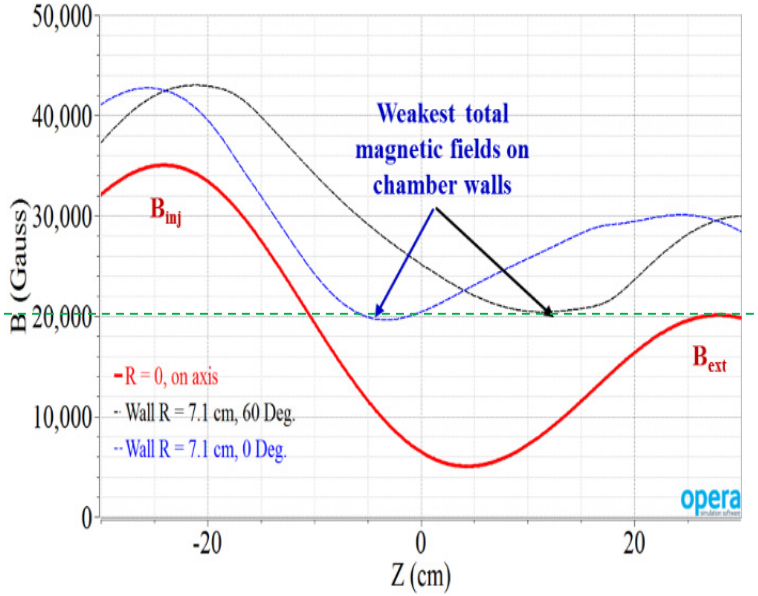

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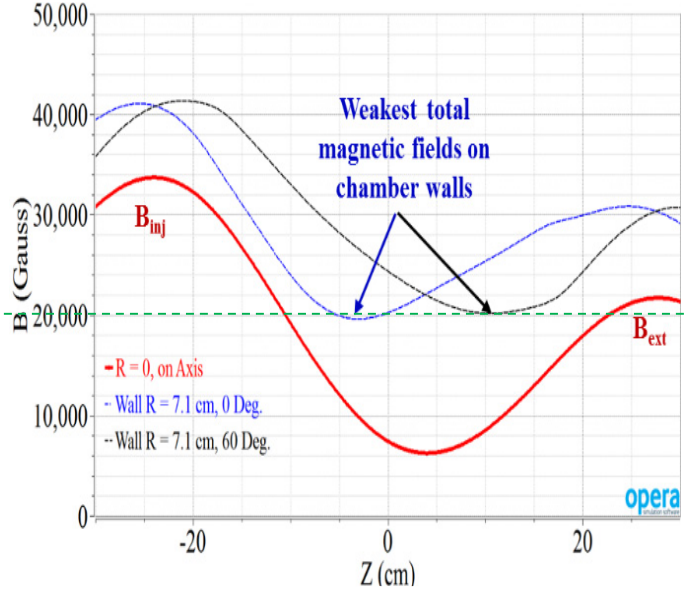

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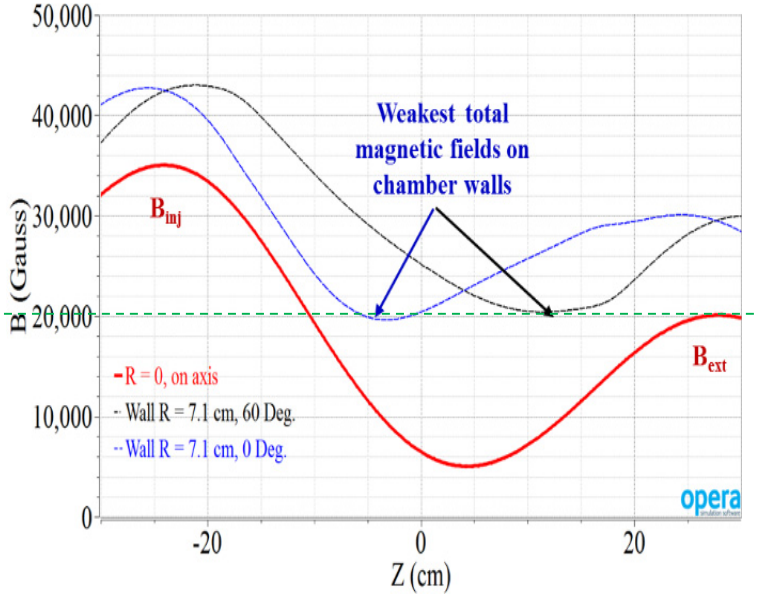

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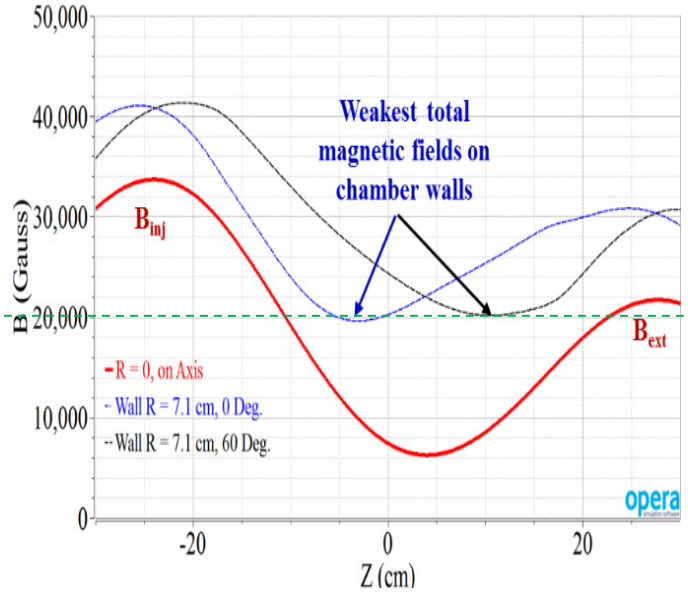

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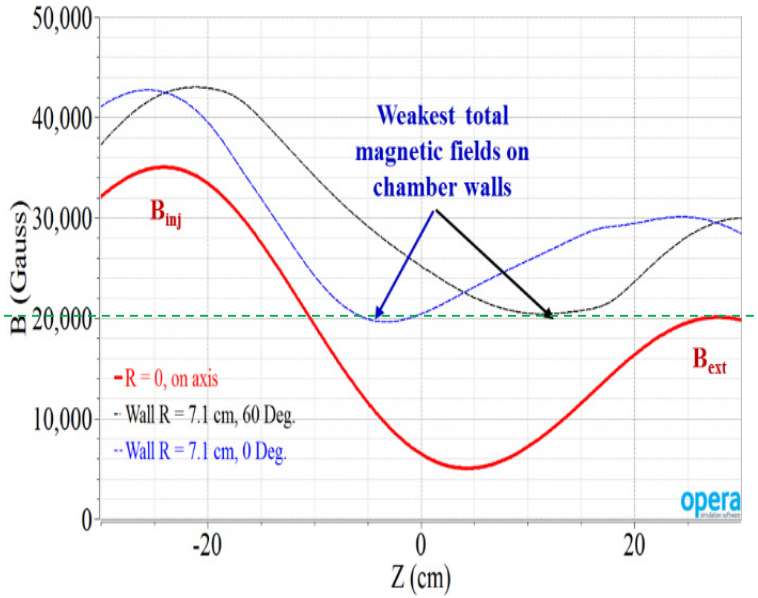

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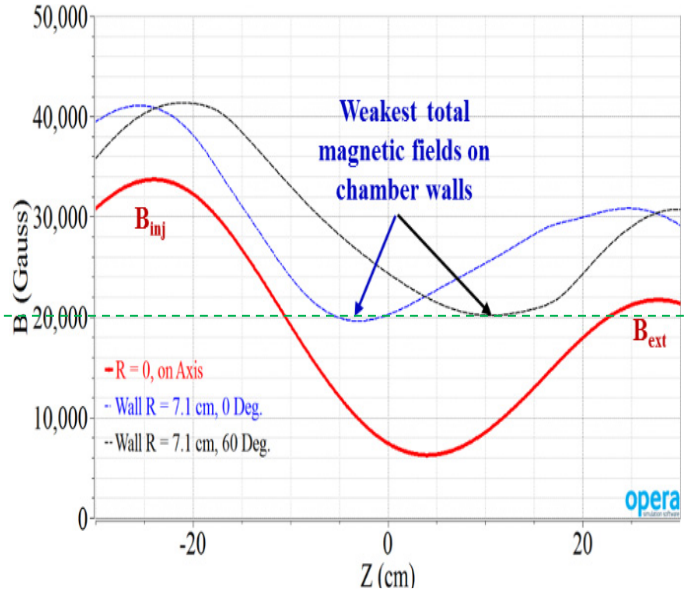

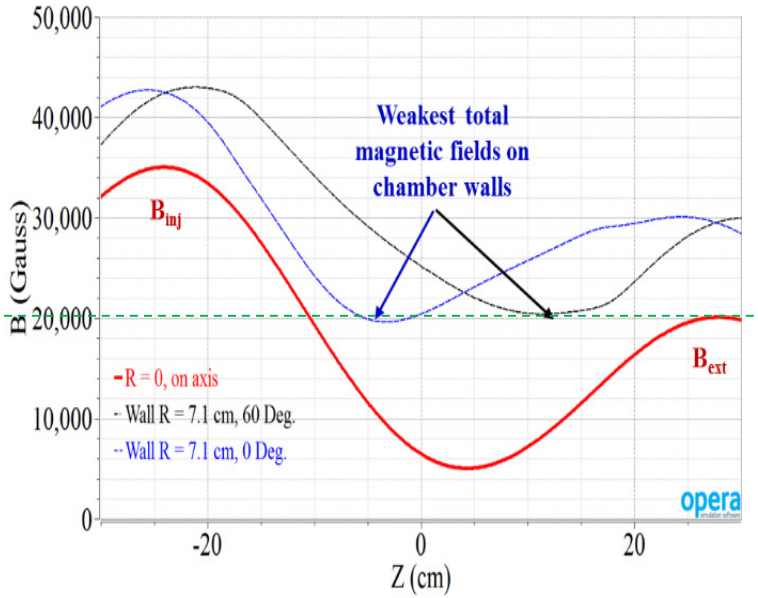

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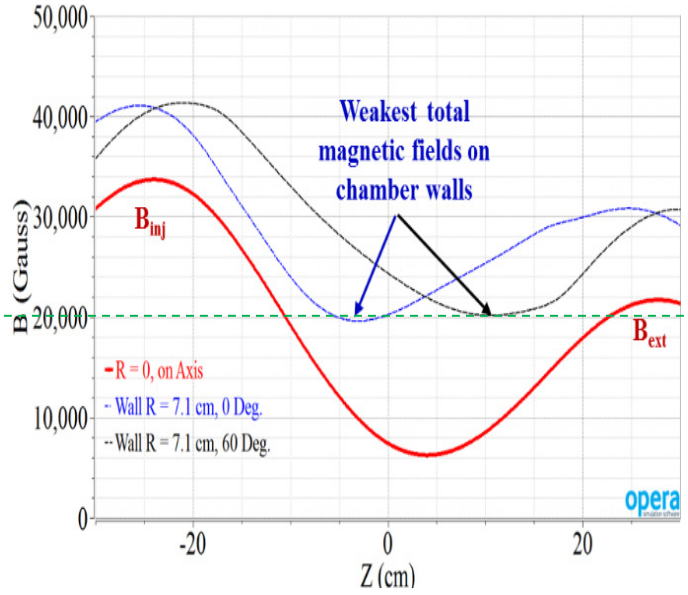

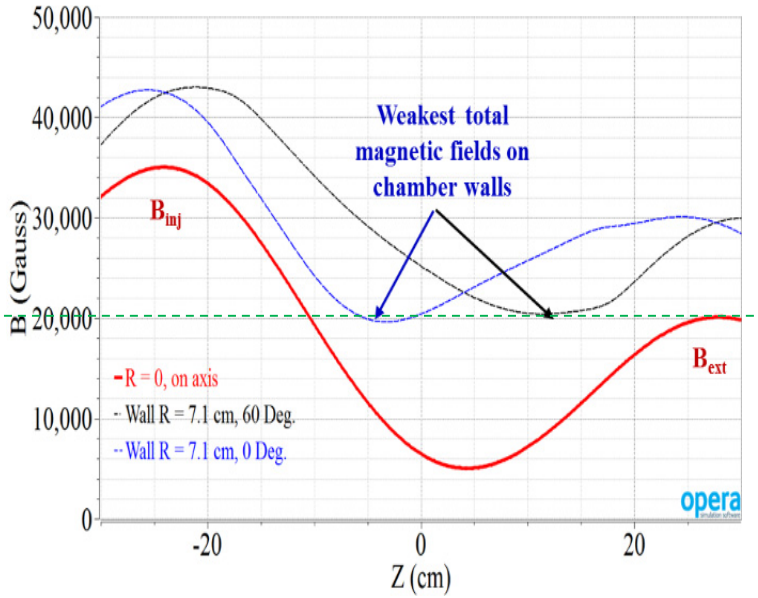

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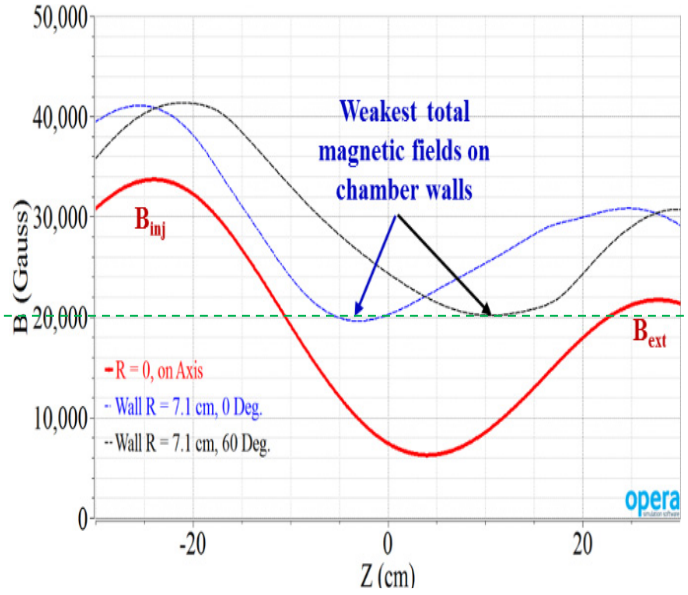

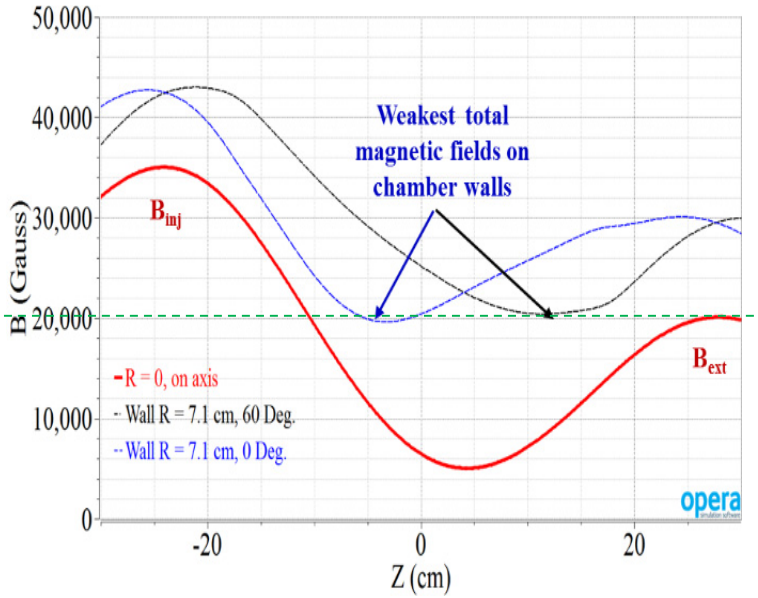

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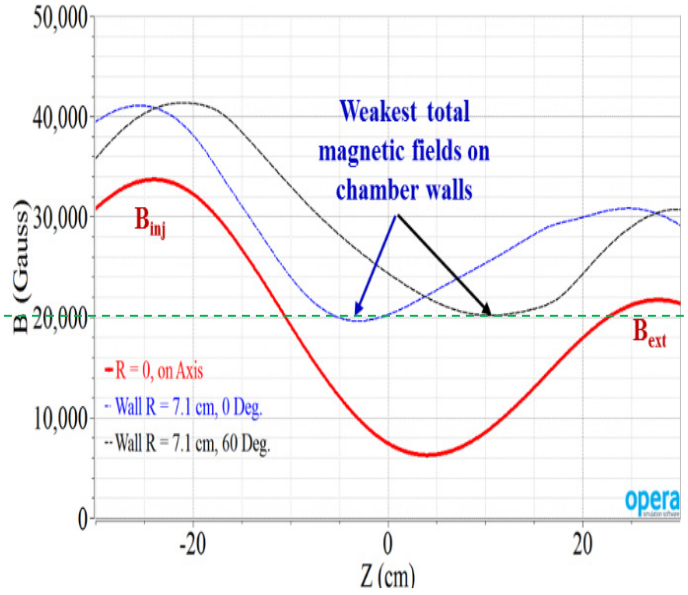

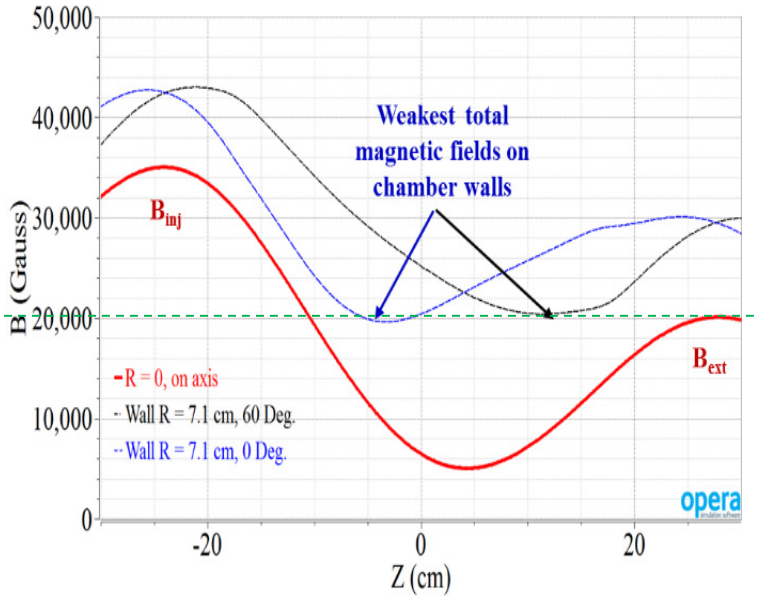

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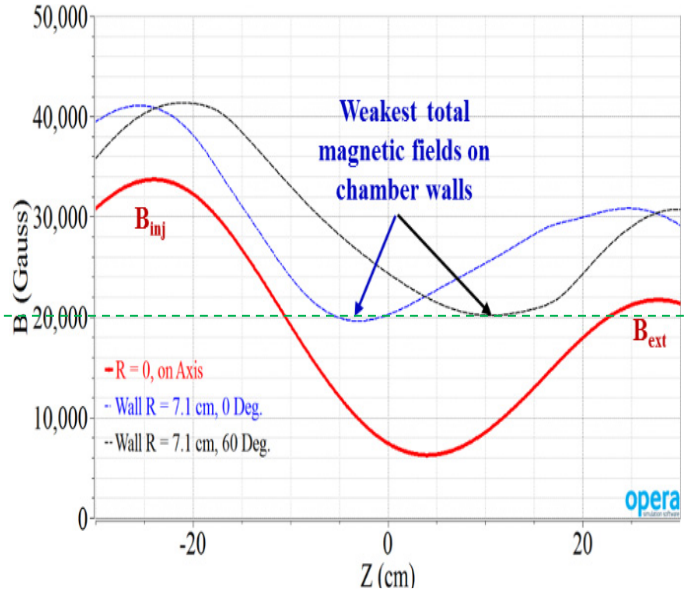

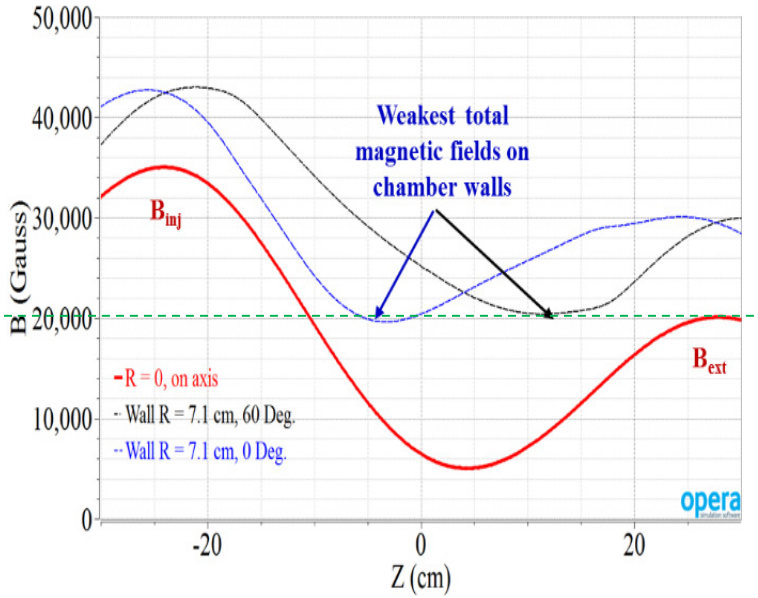

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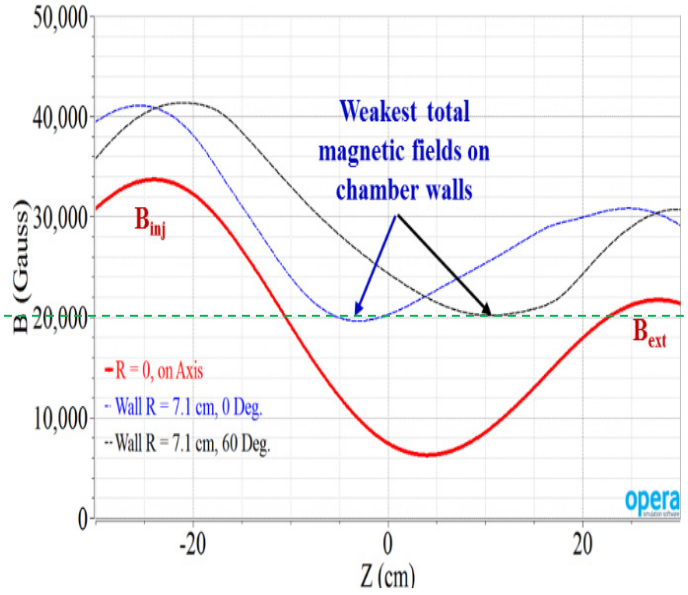

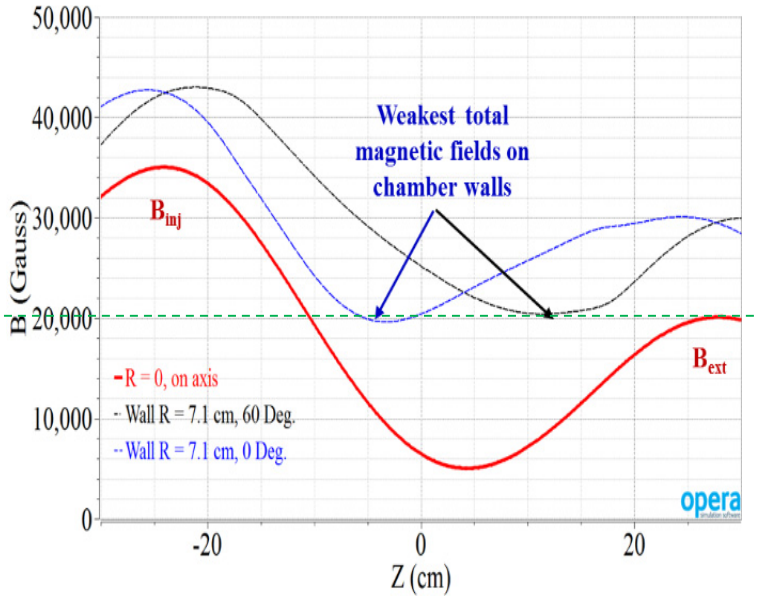

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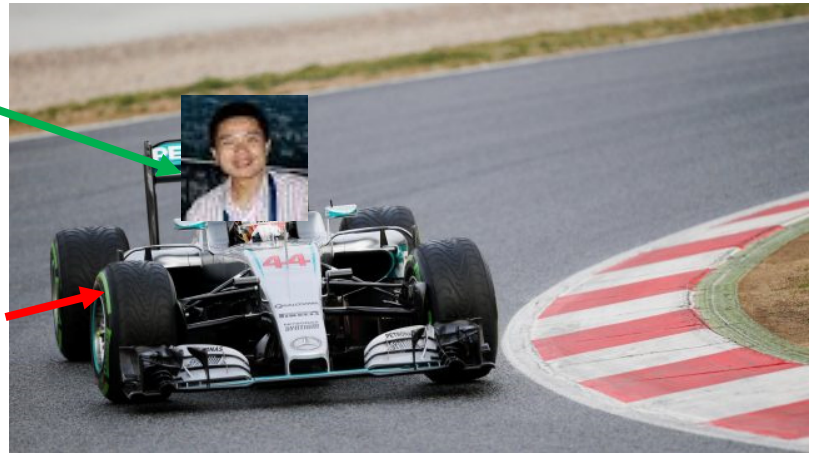

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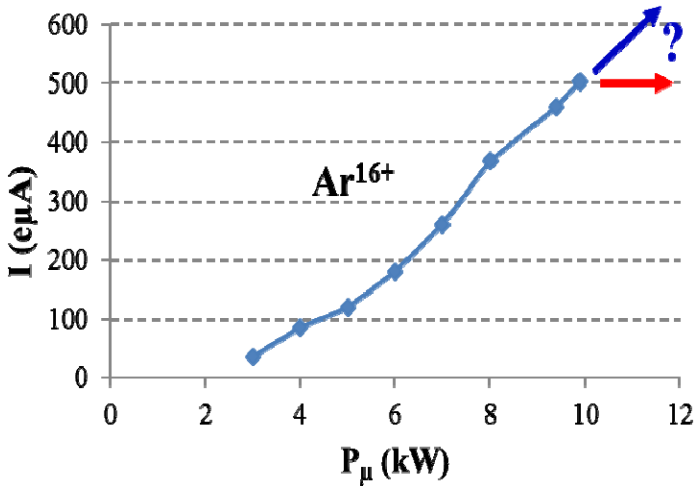
Intensity versus microwave Power

$$I_q \propto n_q/\tau_q \propto P_\mu$$



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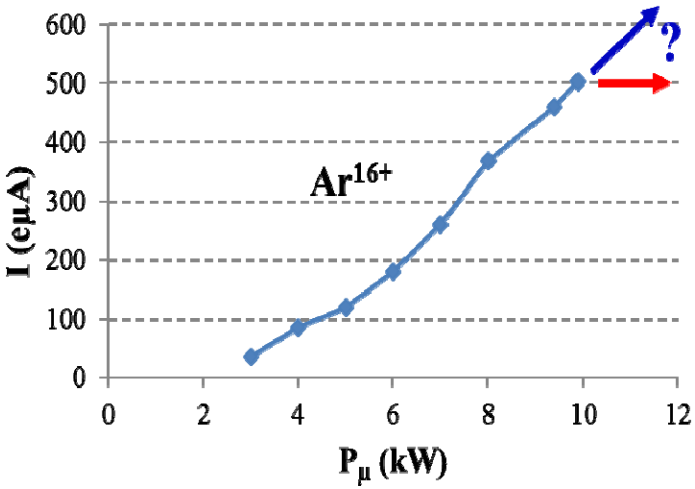

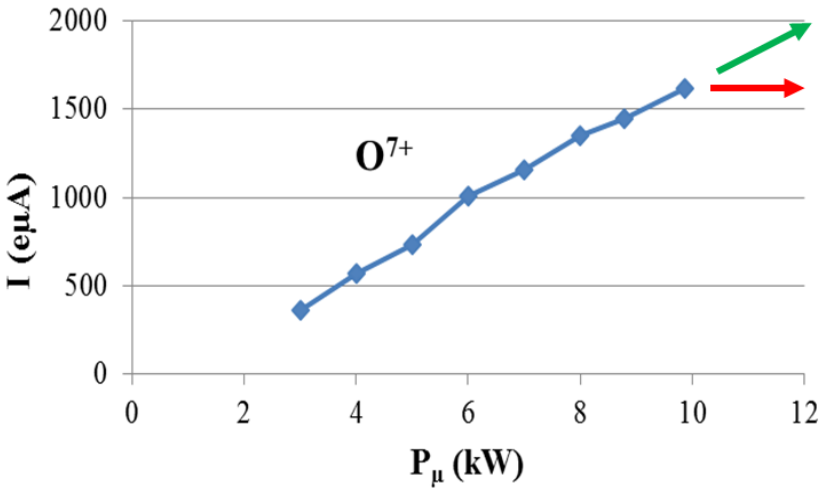

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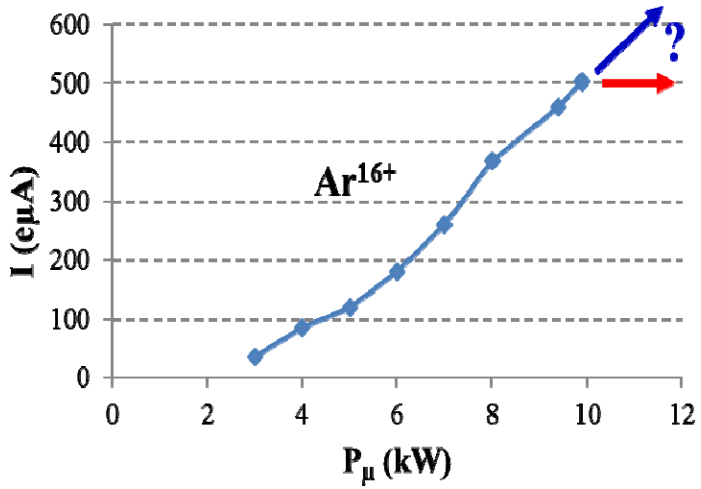

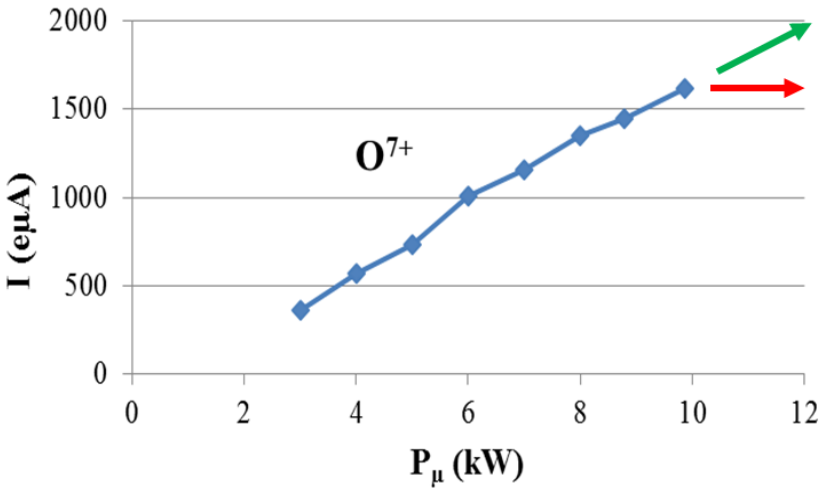

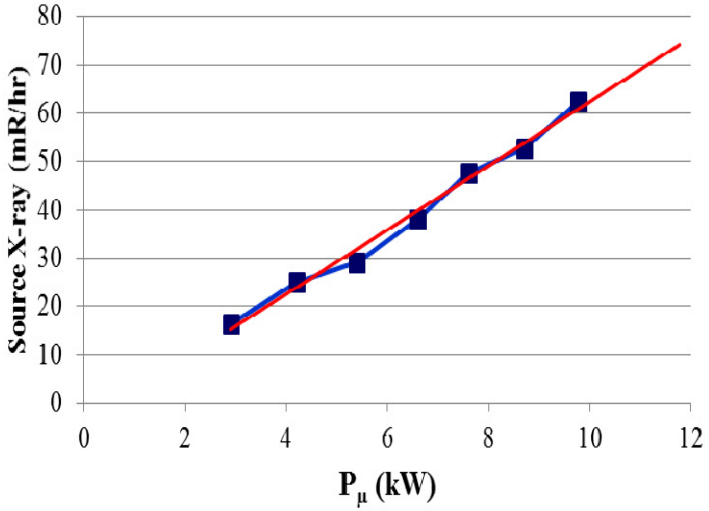

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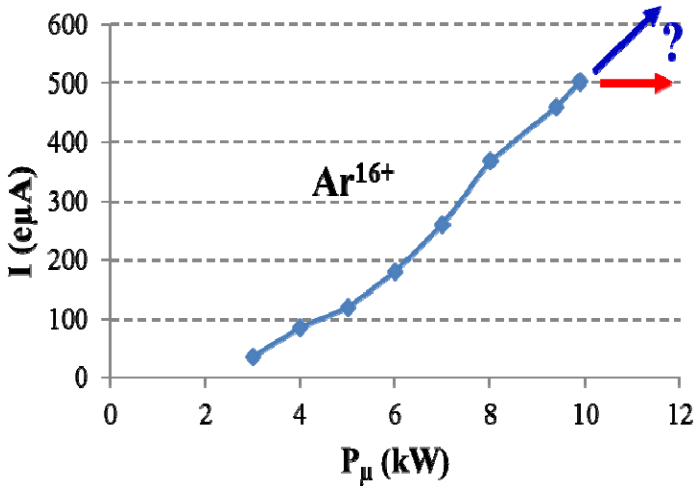

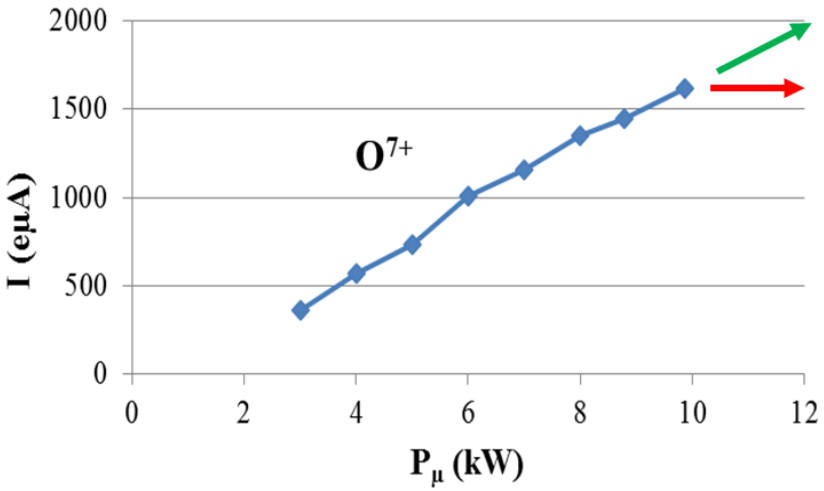

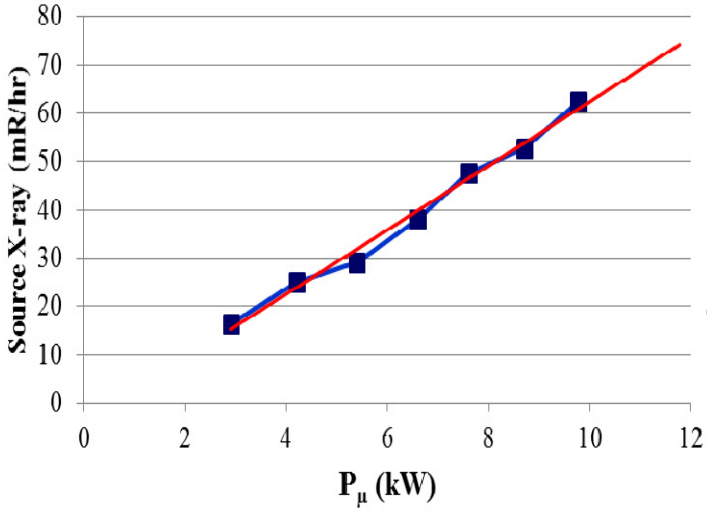

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(Janilee's talk: MOCO04)

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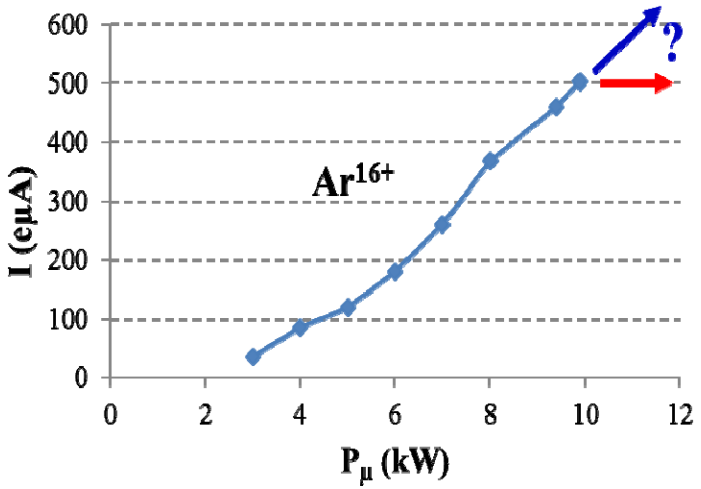
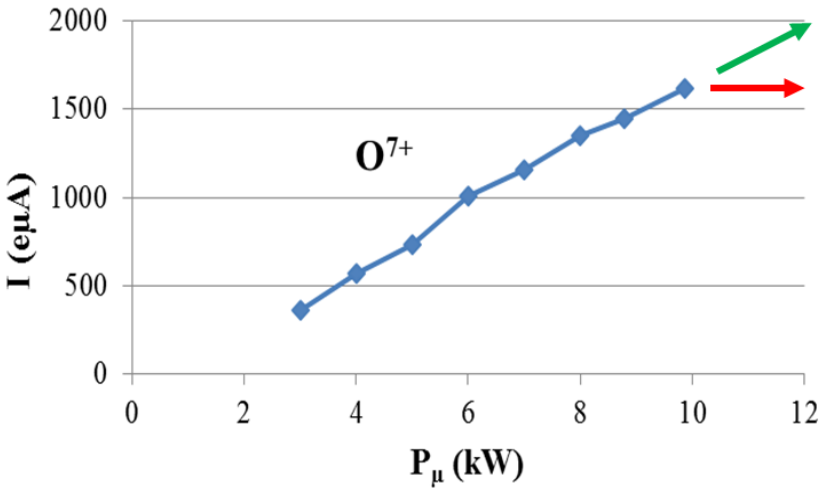
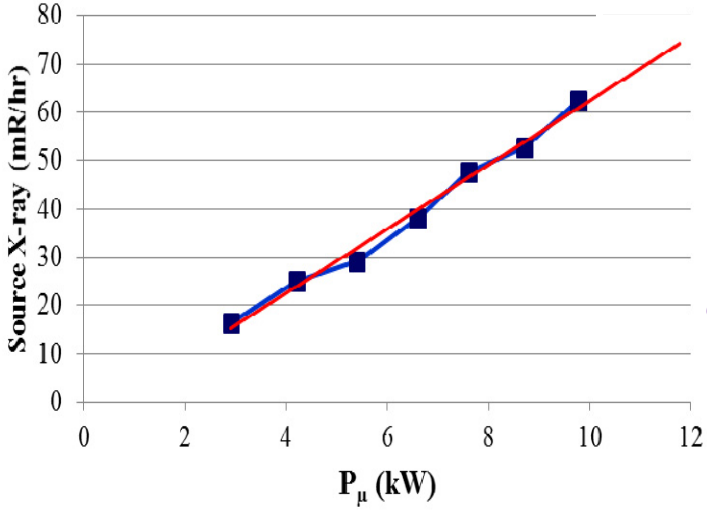




Bremsstrahlung Radiations



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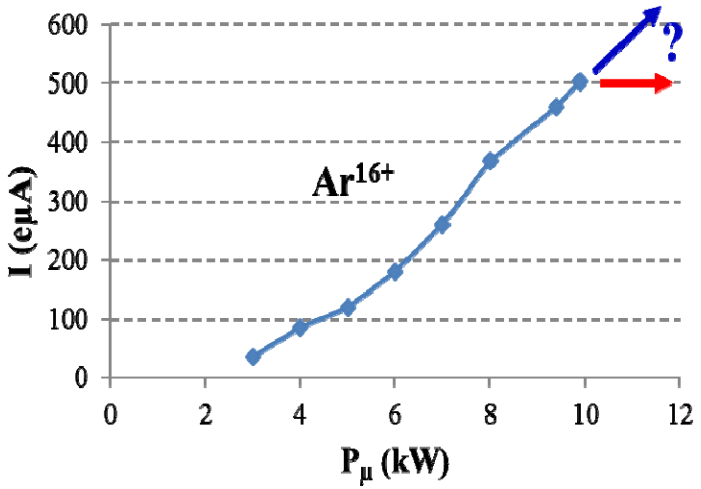

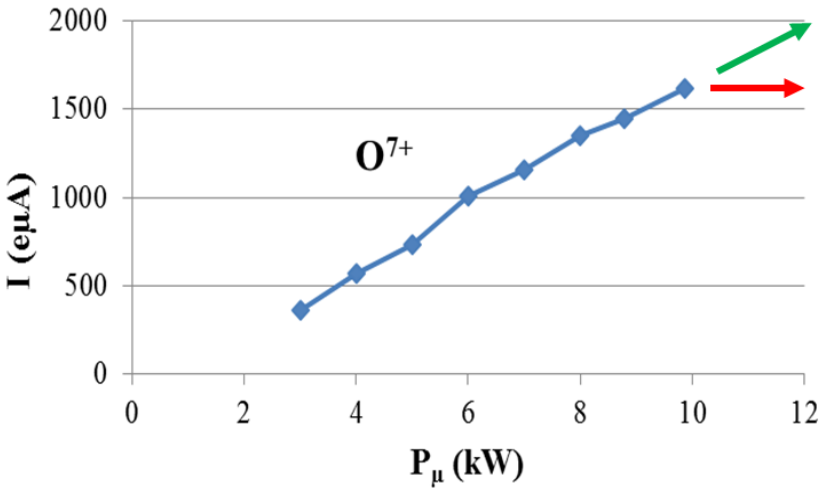

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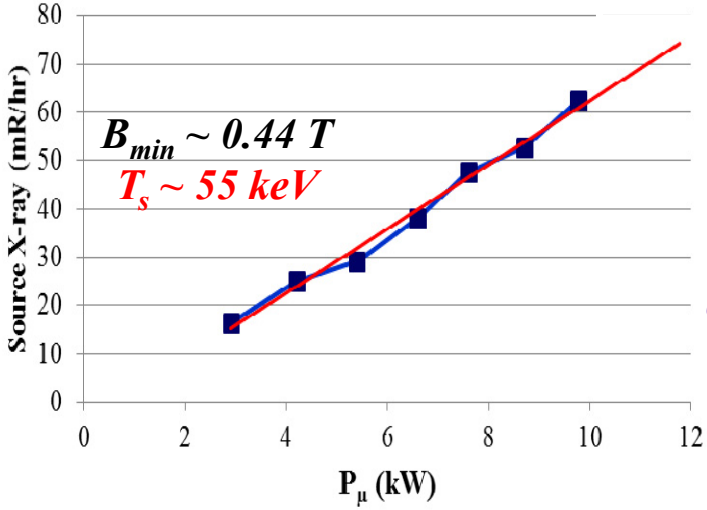

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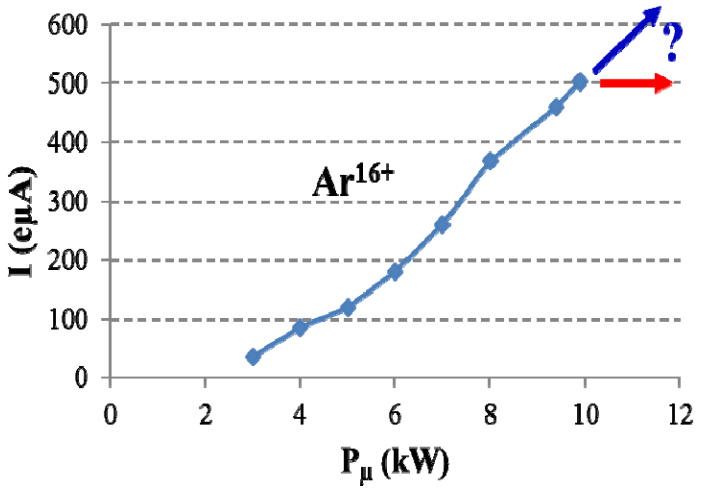

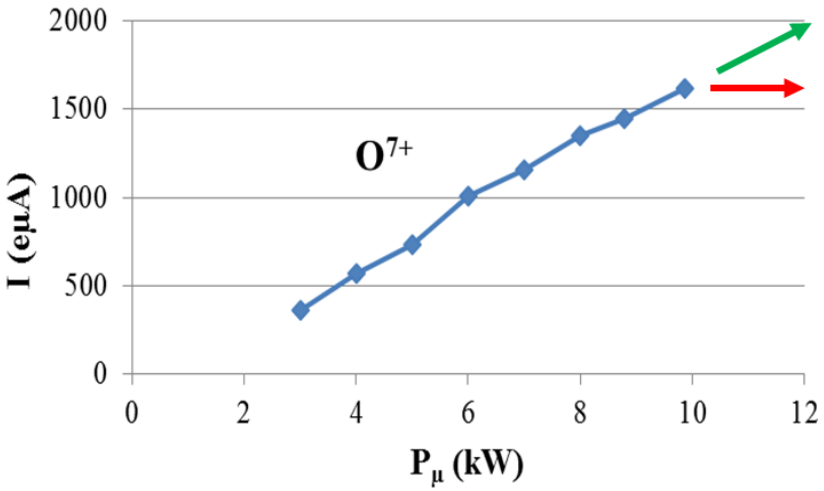

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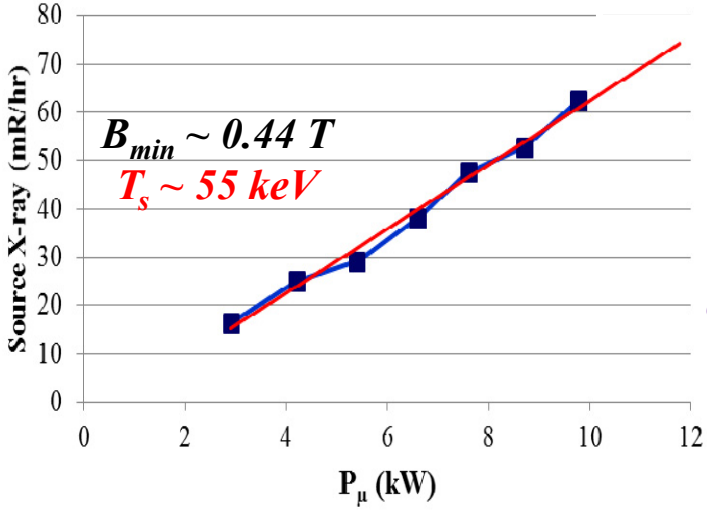

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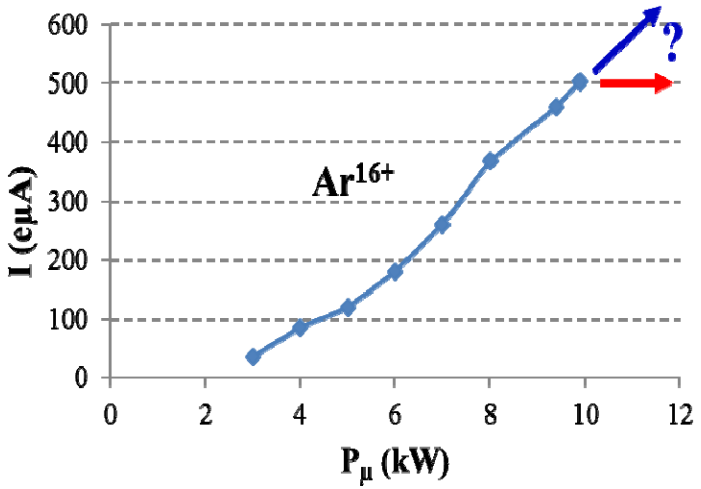

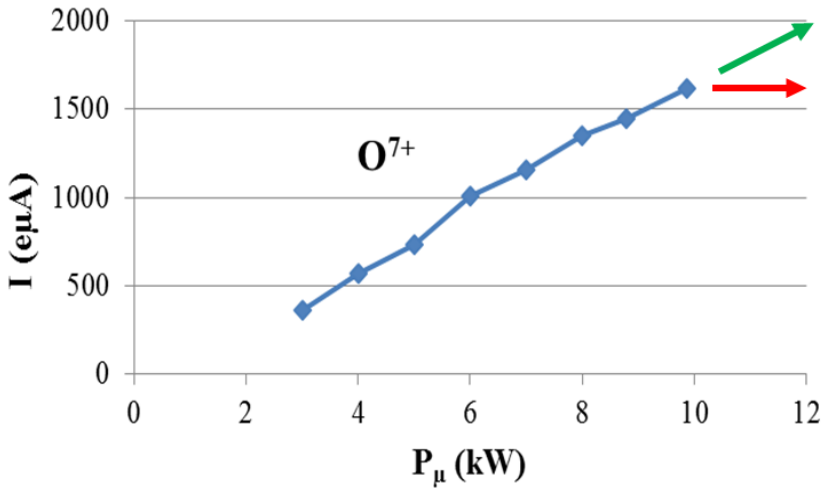

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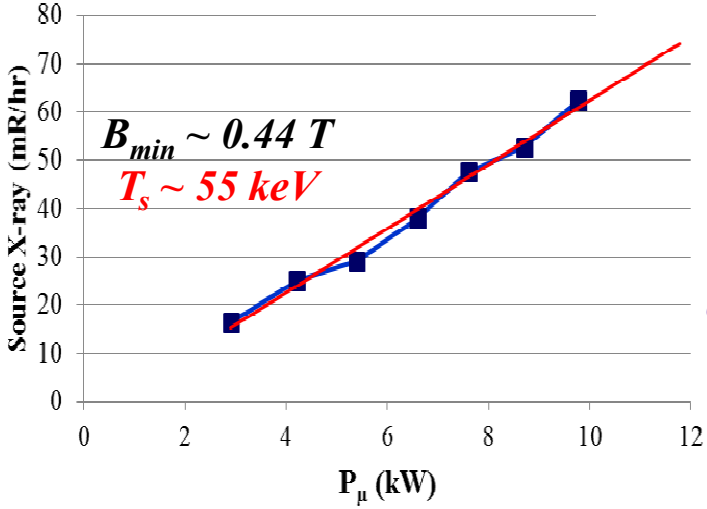

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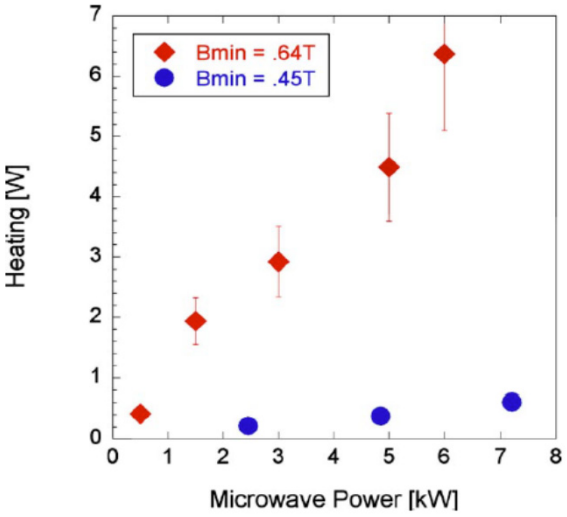

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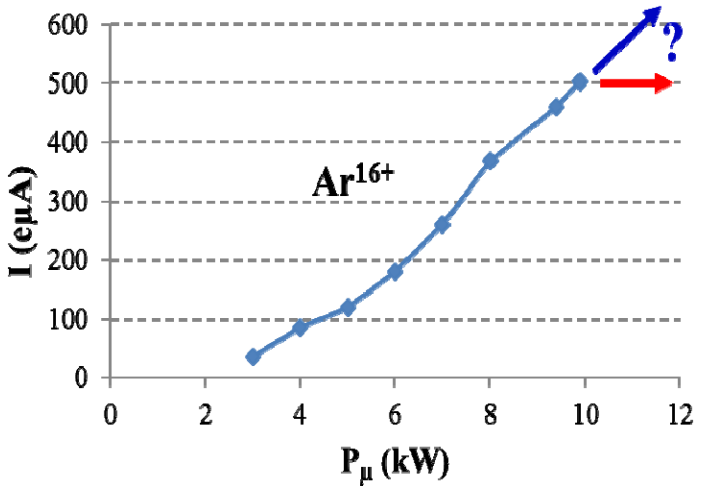

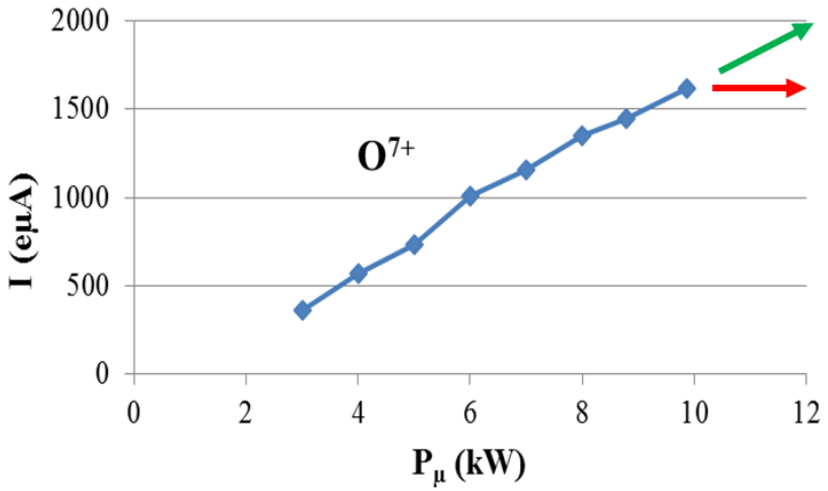

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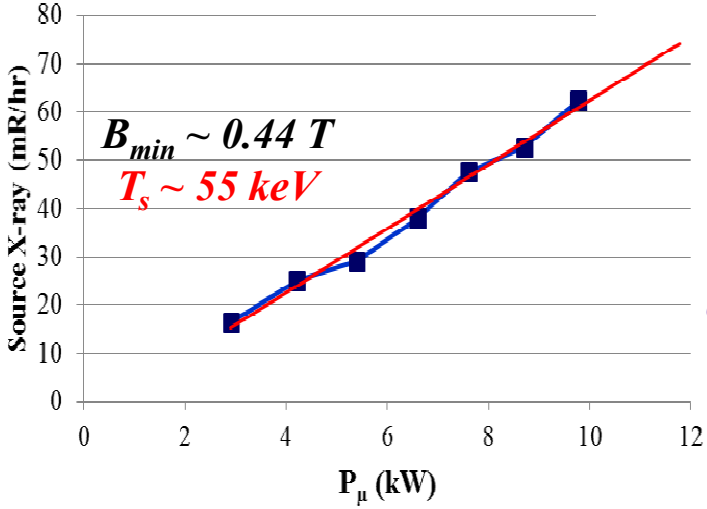

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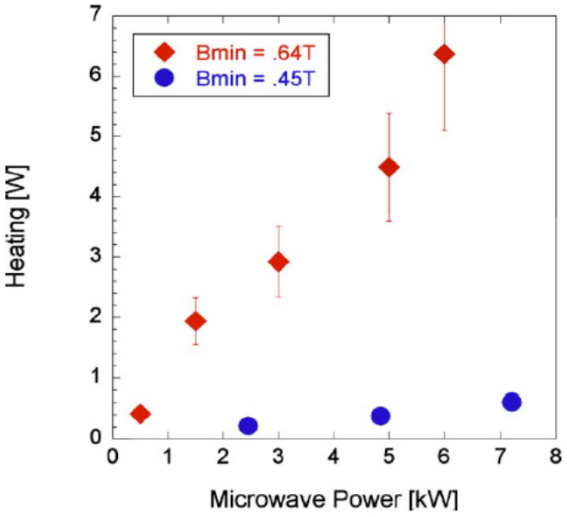

2009

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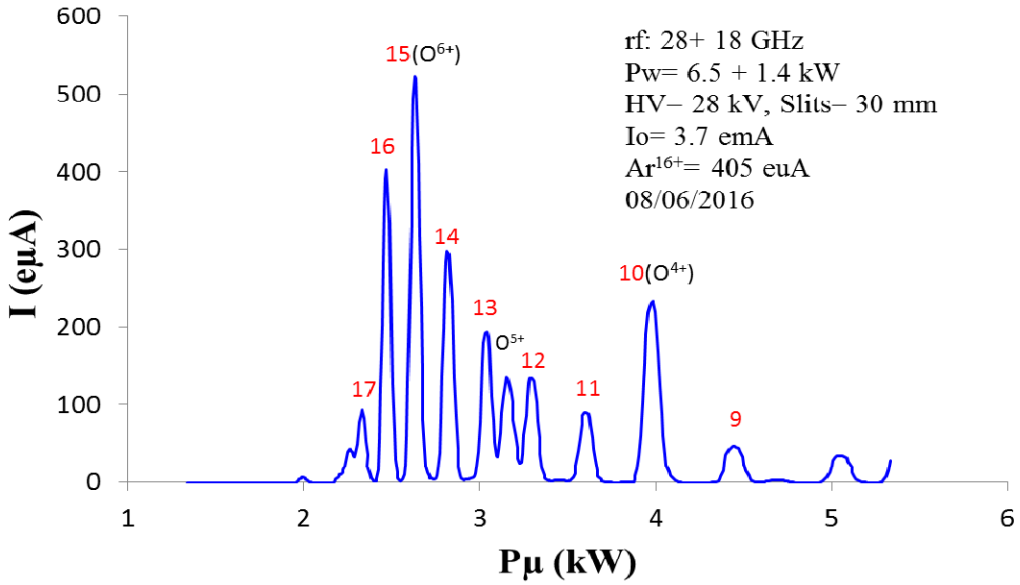
Beam Stability at High Microwave Power



Likely peaked at 16+.

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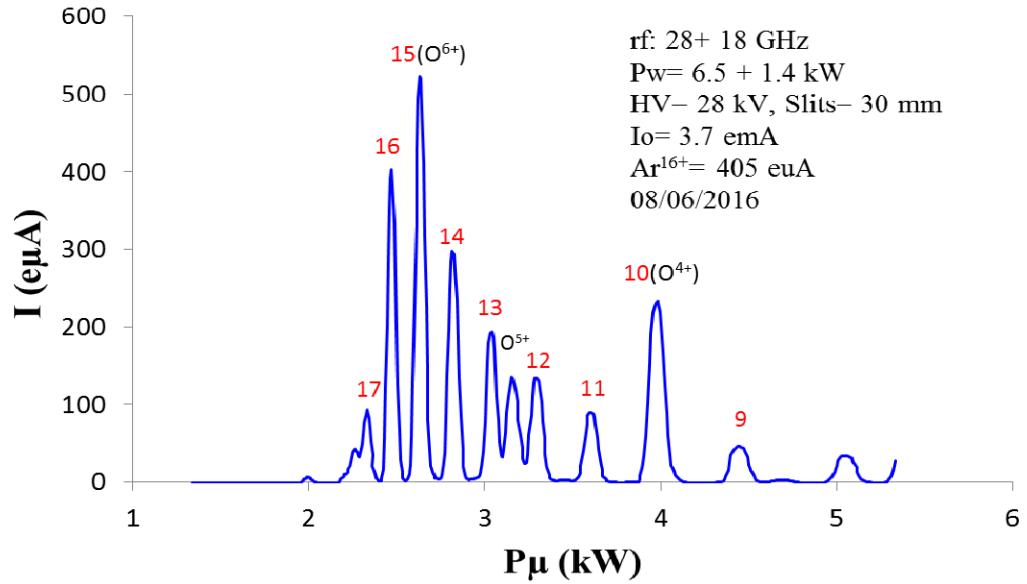

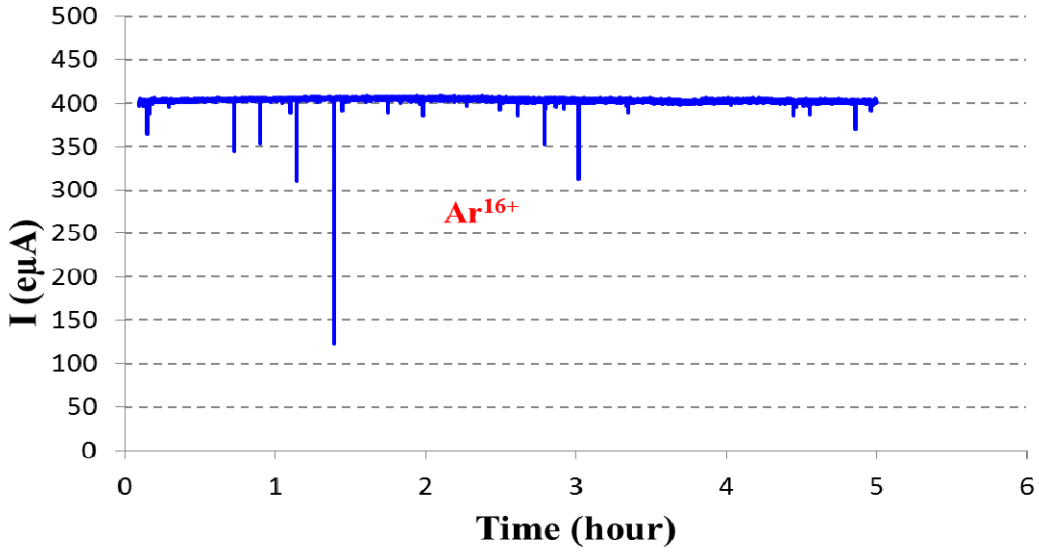

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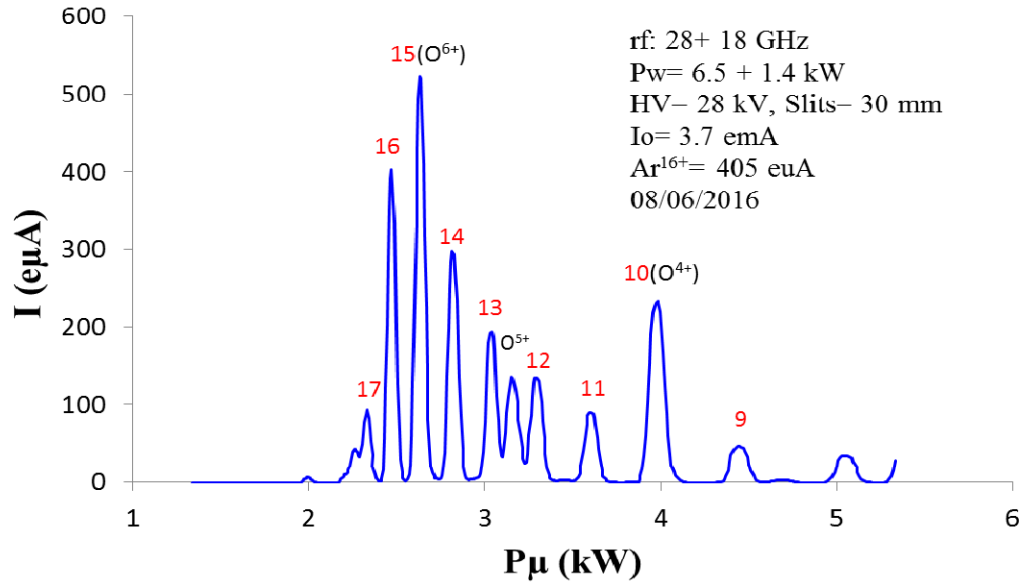

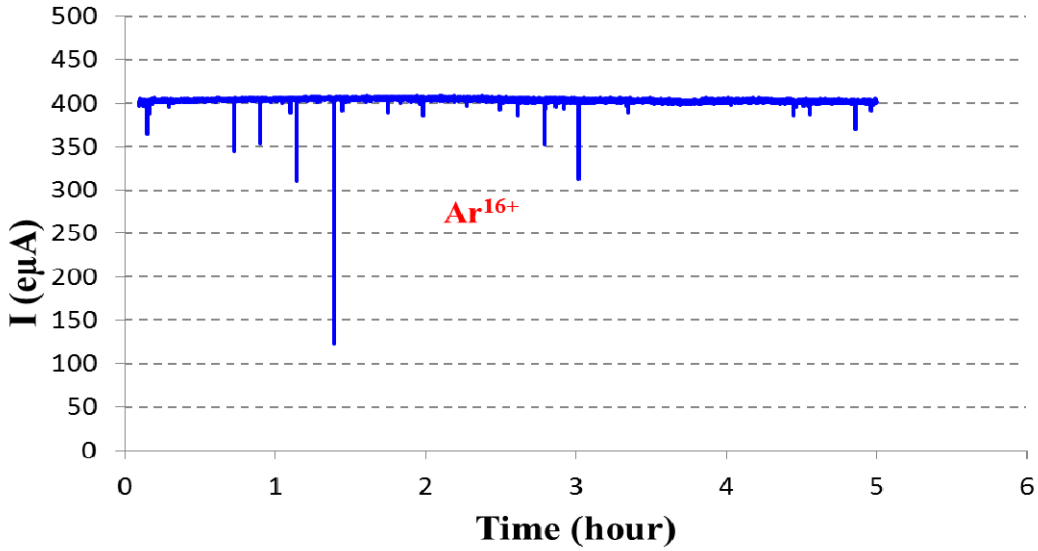

Likely peaked at 16+.

The beam intensity is flat over 5 hours except a few trips. It should work like this for days and weeks if all inputs kept stable.

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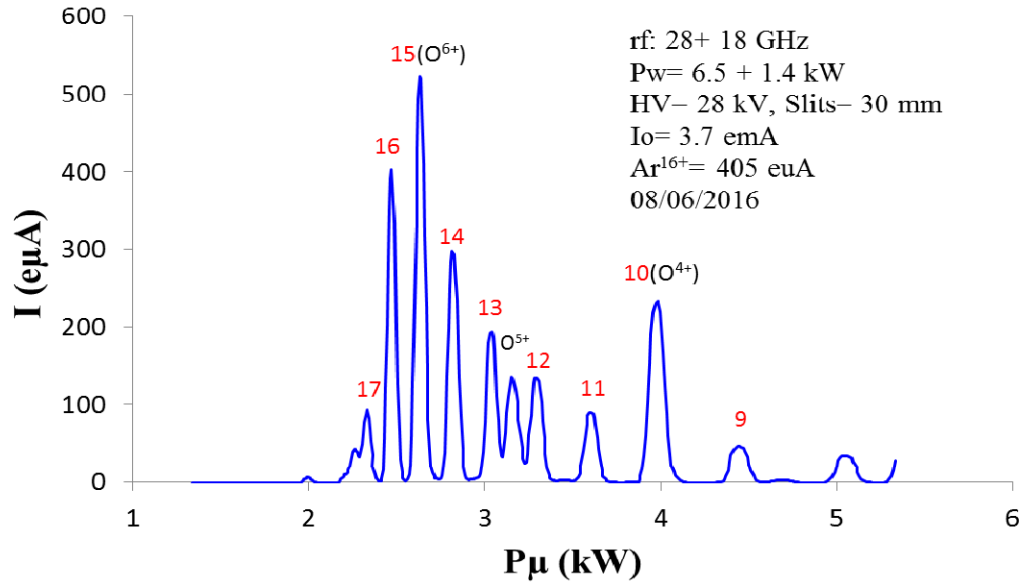

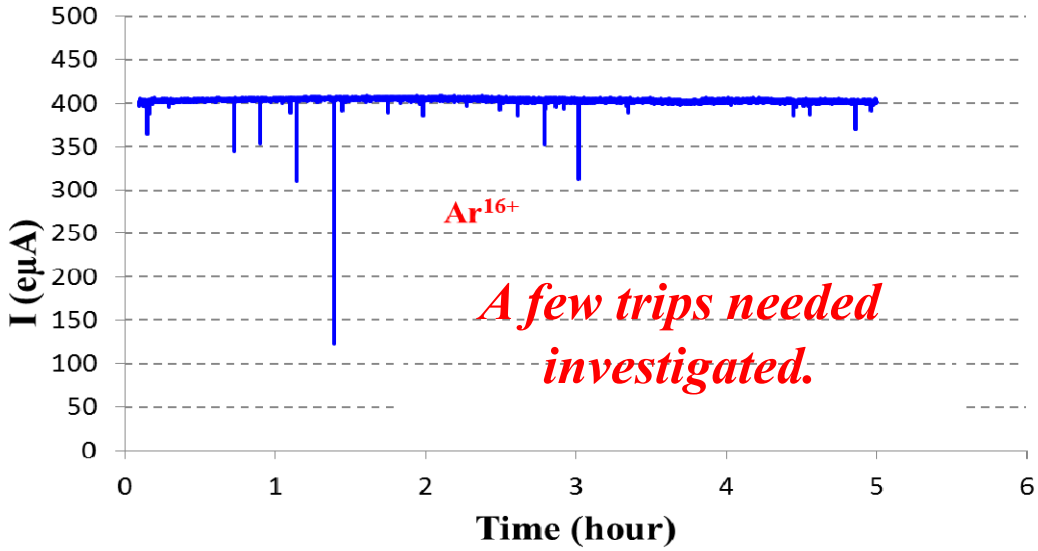

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- The enhancement came from a combination of the modifications discussed. However we do not know which of the remedies contributes most to the enhancement, due to that we did not explore thoroughly one by one;
- ***Tests are continuing for other ion beams. We plan to further test two more different sizes, Ø15 and Ø25 mm, of the 28 GHz coupling waveguides to determine a better coupling the 28 GHz microwaves to VENUS.***
- ***Even though so far no any conclusive evidence supports the role of the microwave mode in the ECRIS performance, investigation of the effects of TE_{01} and TE_{11} microwaves has also been planned for future developments.***

For Your Attention!