

# **High Quality operation of submillimeter wave gyrotron for plasma diagnostics application**

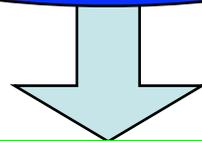
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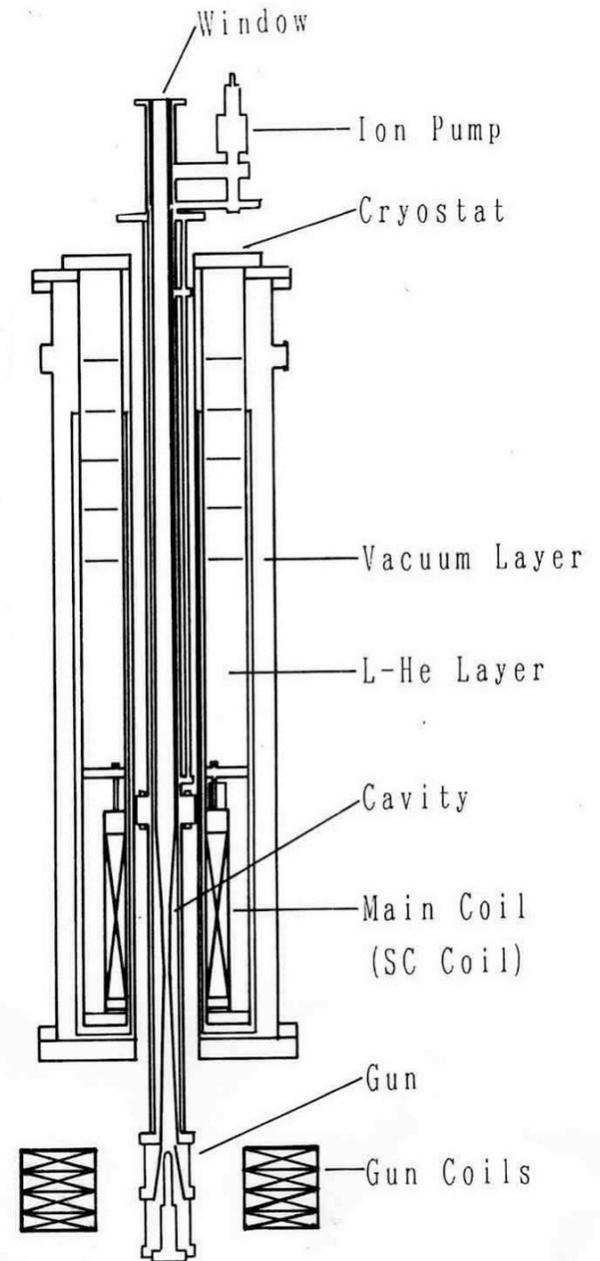
**Application of Gyrotron FU II**

**Gyrotron FU II**

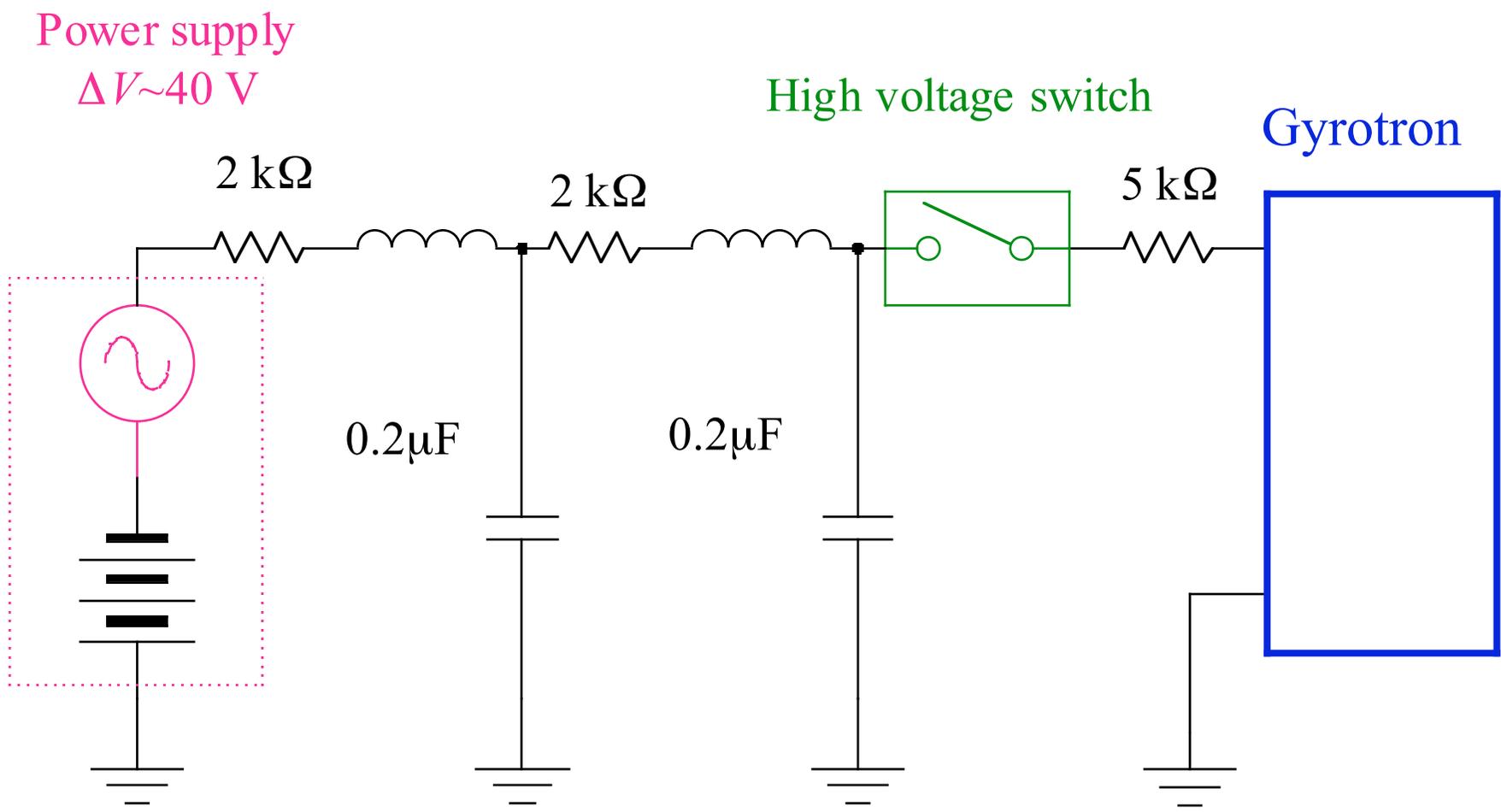
- submillimeter wave length range ( $f=354$  GHz)
- high output power (**110 W**)
- long pulse operation (2.0 s)
- **circular waveguide mode output** ( $TE_{16}$  mode)

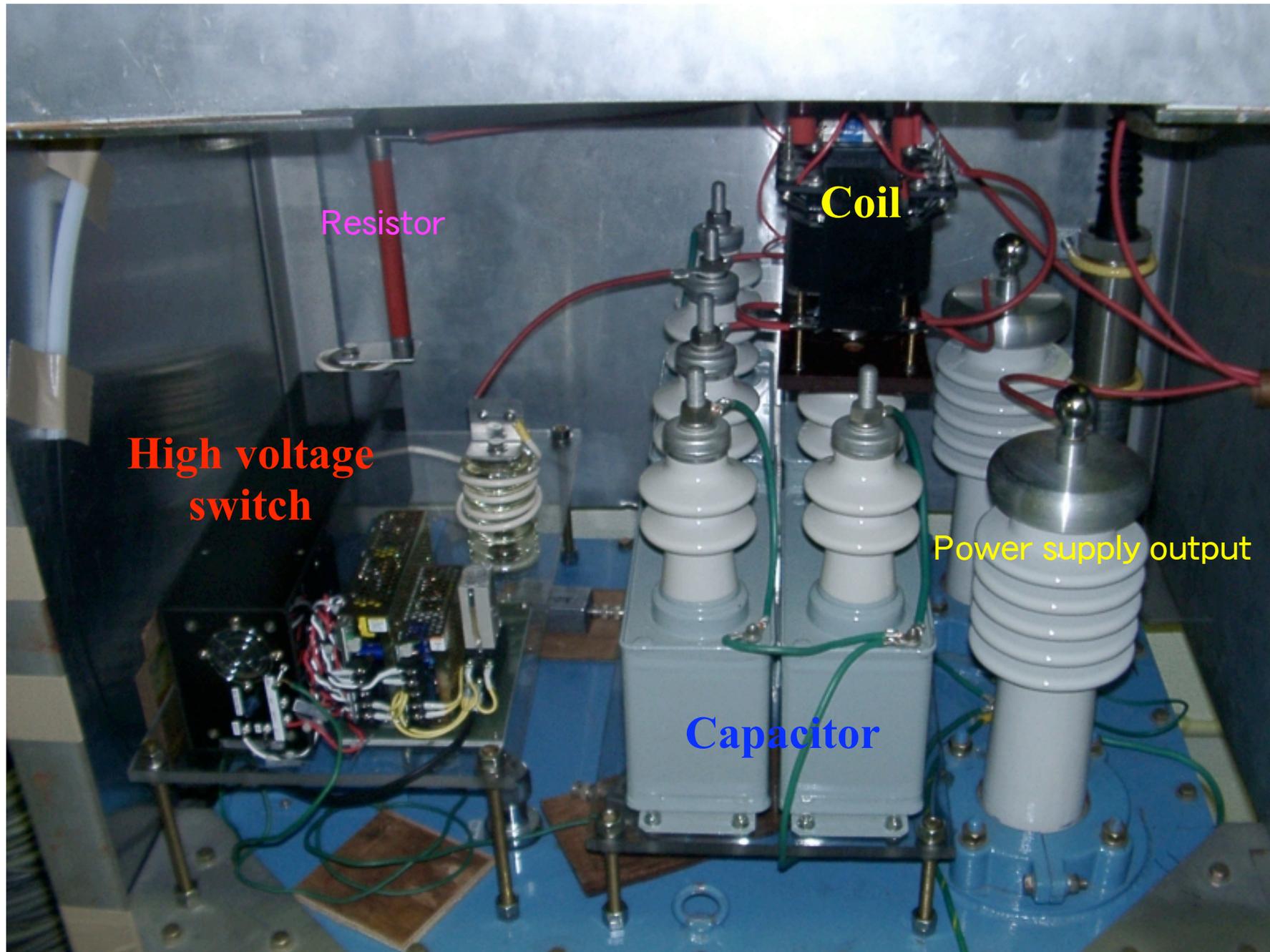


- **stabilization of frequency of gyrotron output** ( $f < 50$  kHz)
- **couple of gyrotron output to plasma** ( $P > \text{several W}$ )



Stabilization of gyrotron output using a smoothing circuit

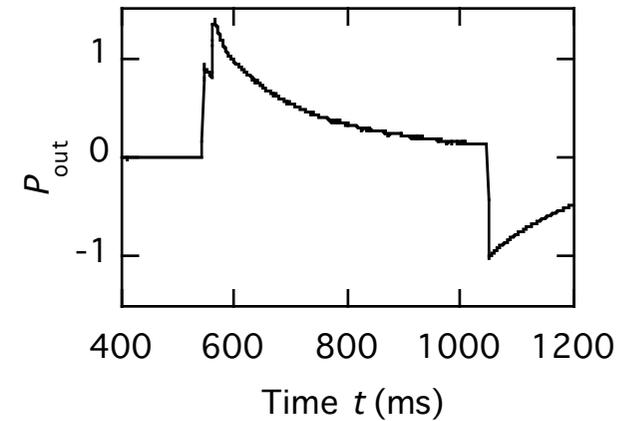
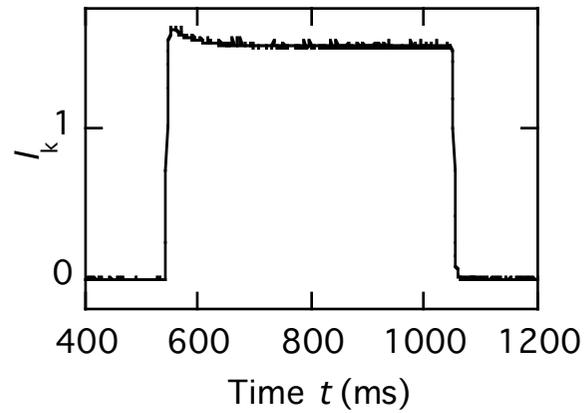
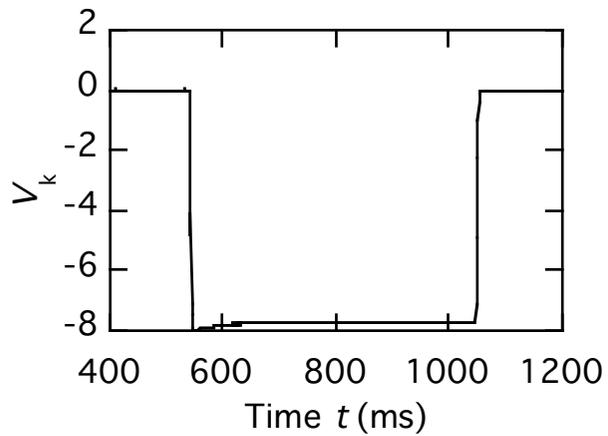




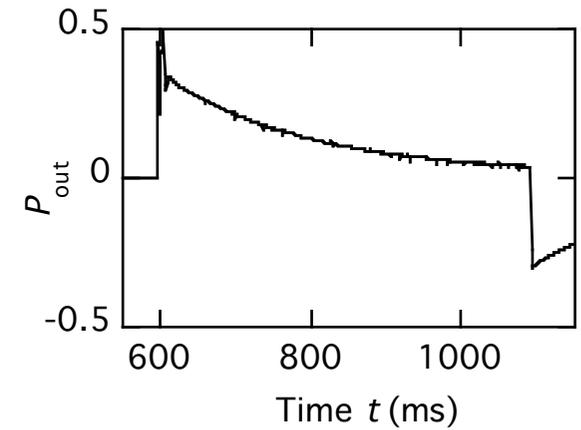
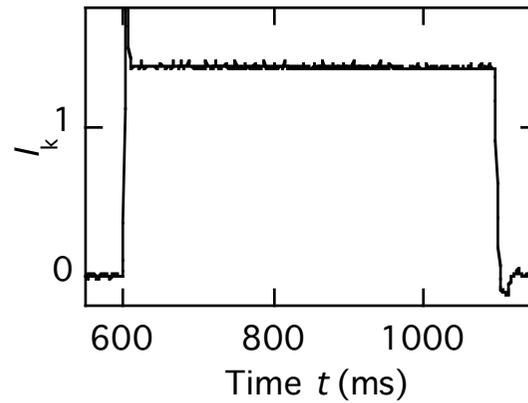
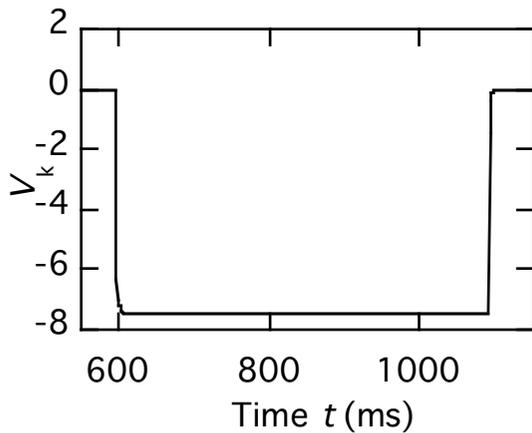


**TE<sub>13</sub> mode,  $f=165$  GHz,  $B_0 = 6.15$  T,  $V_k = -19.5$  kV,  $I_k = 85$  mA**

**Without a smoothing circuit**



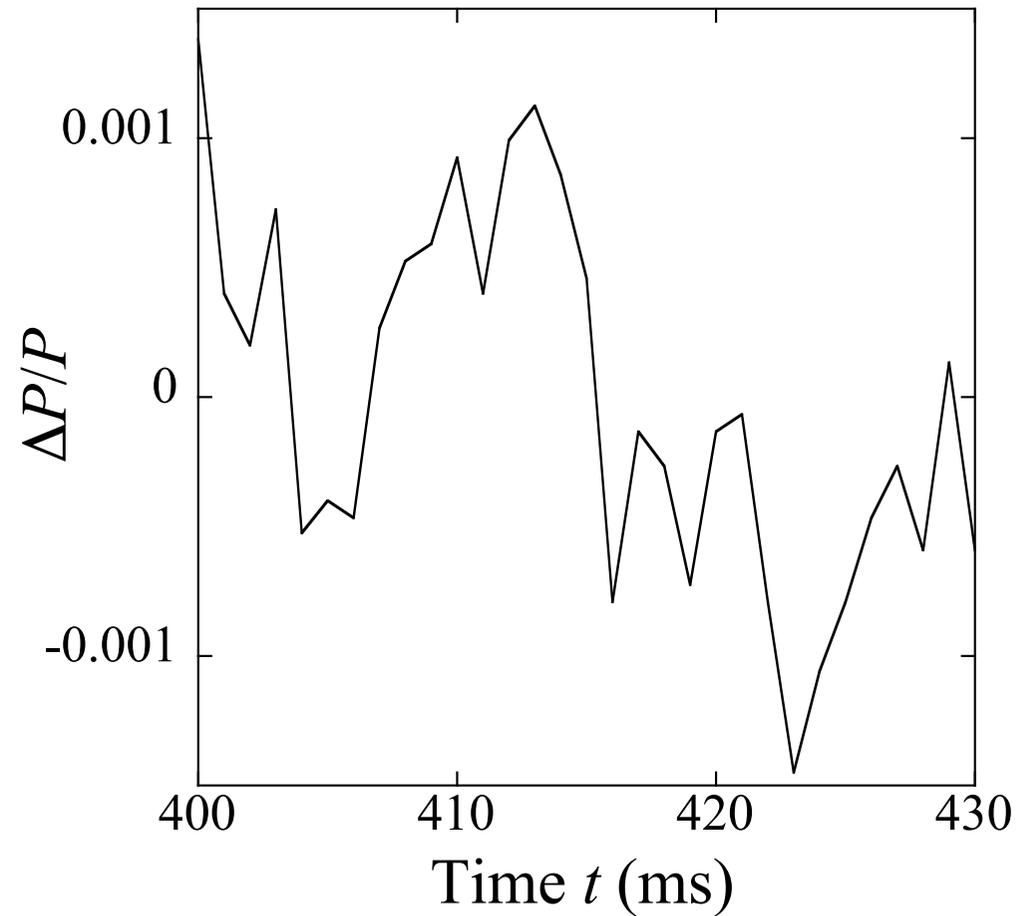
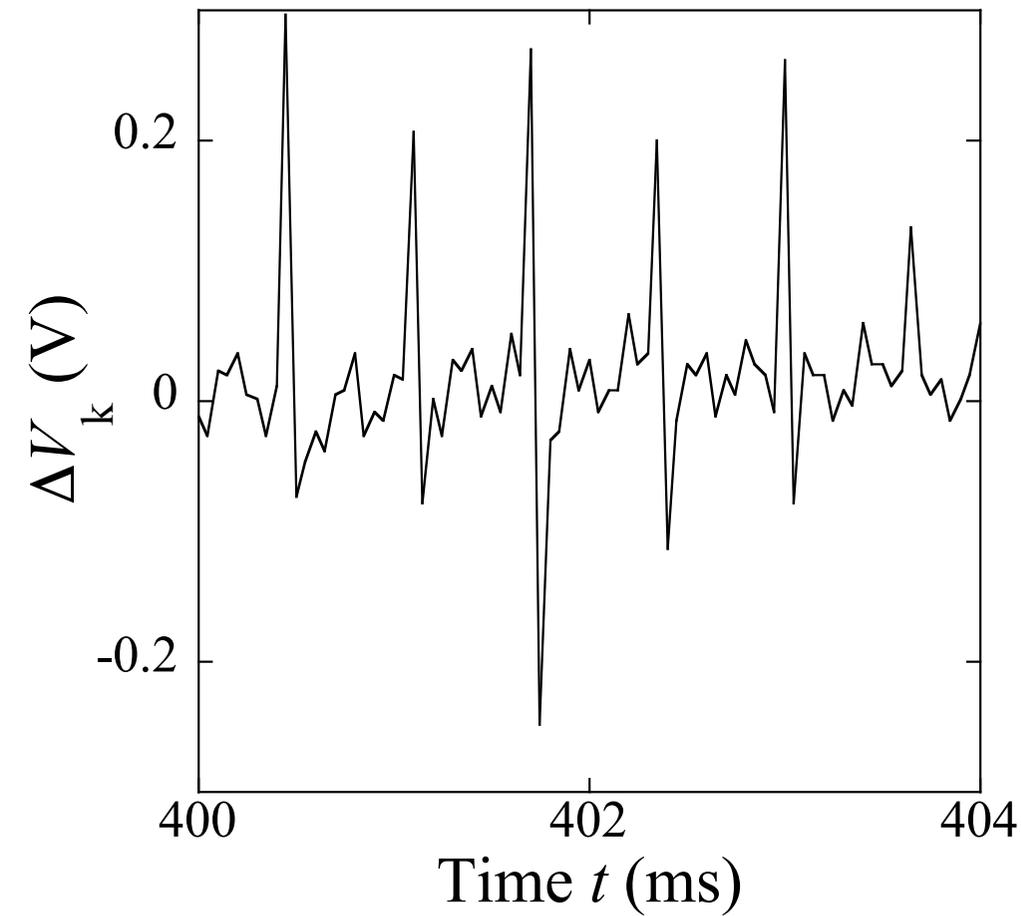
**With a smoothing circuit**



With a smoothing circuit

$\Delta V_k = 0.5V$

$\Delta P/P = 1\%$

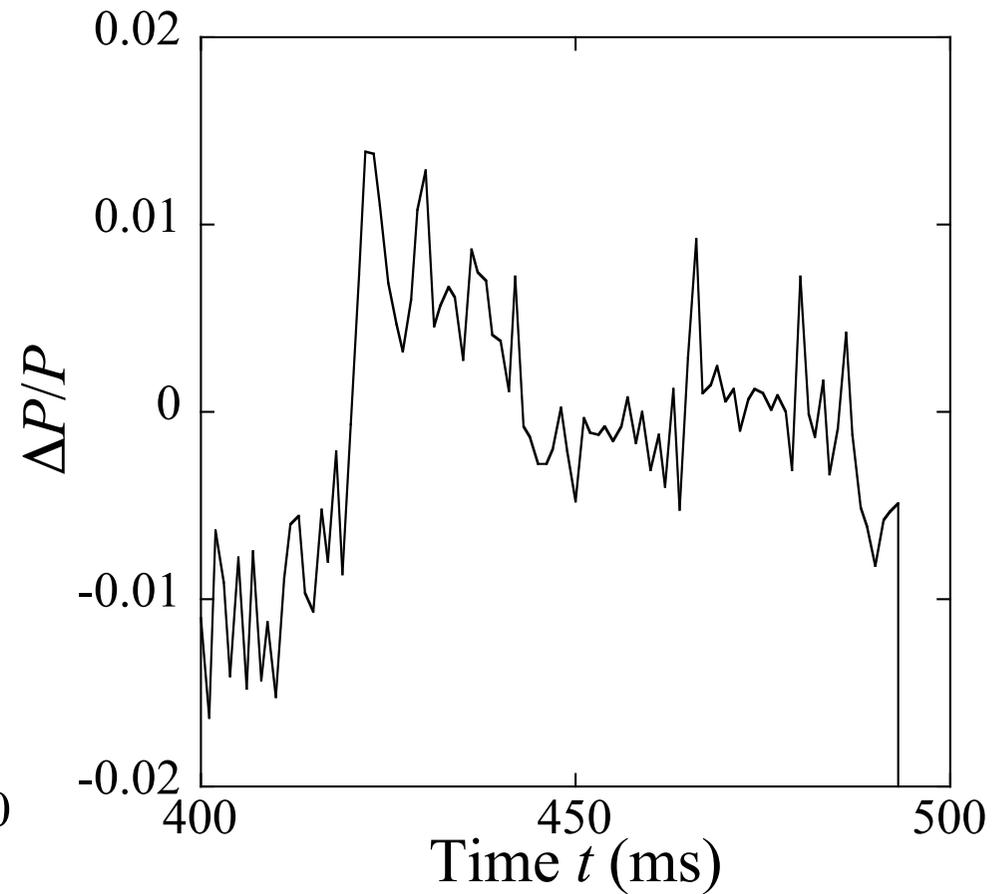
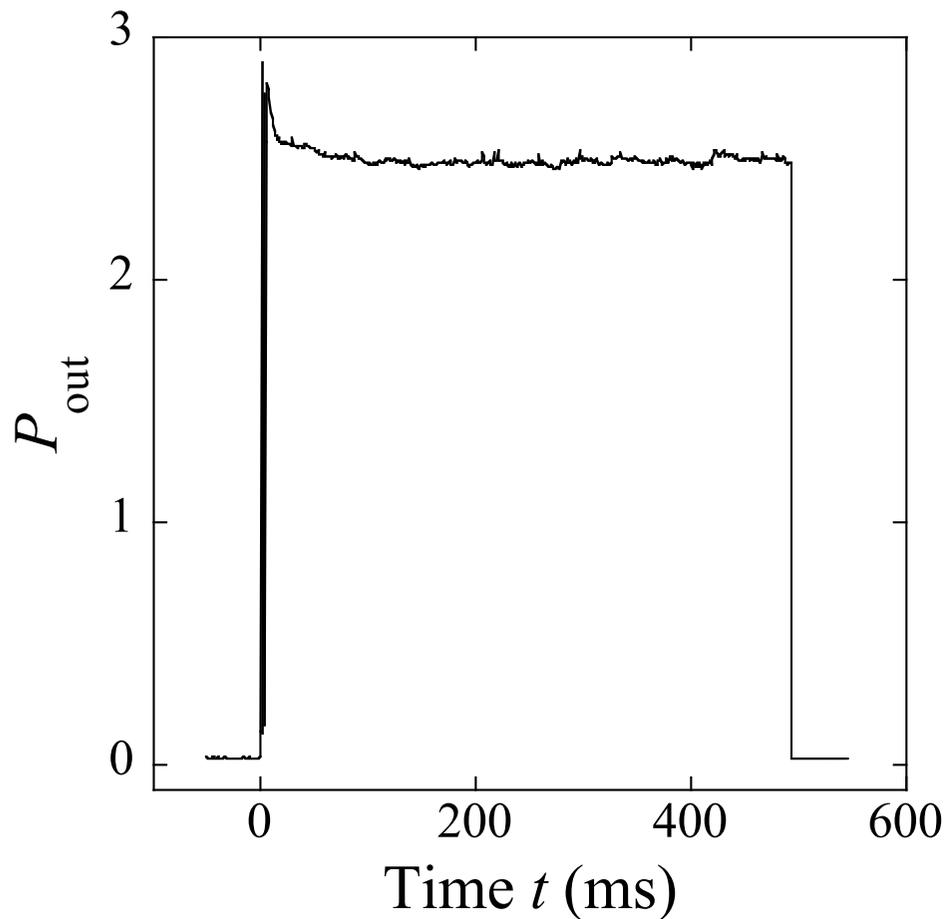


**With a smoothing circuit**

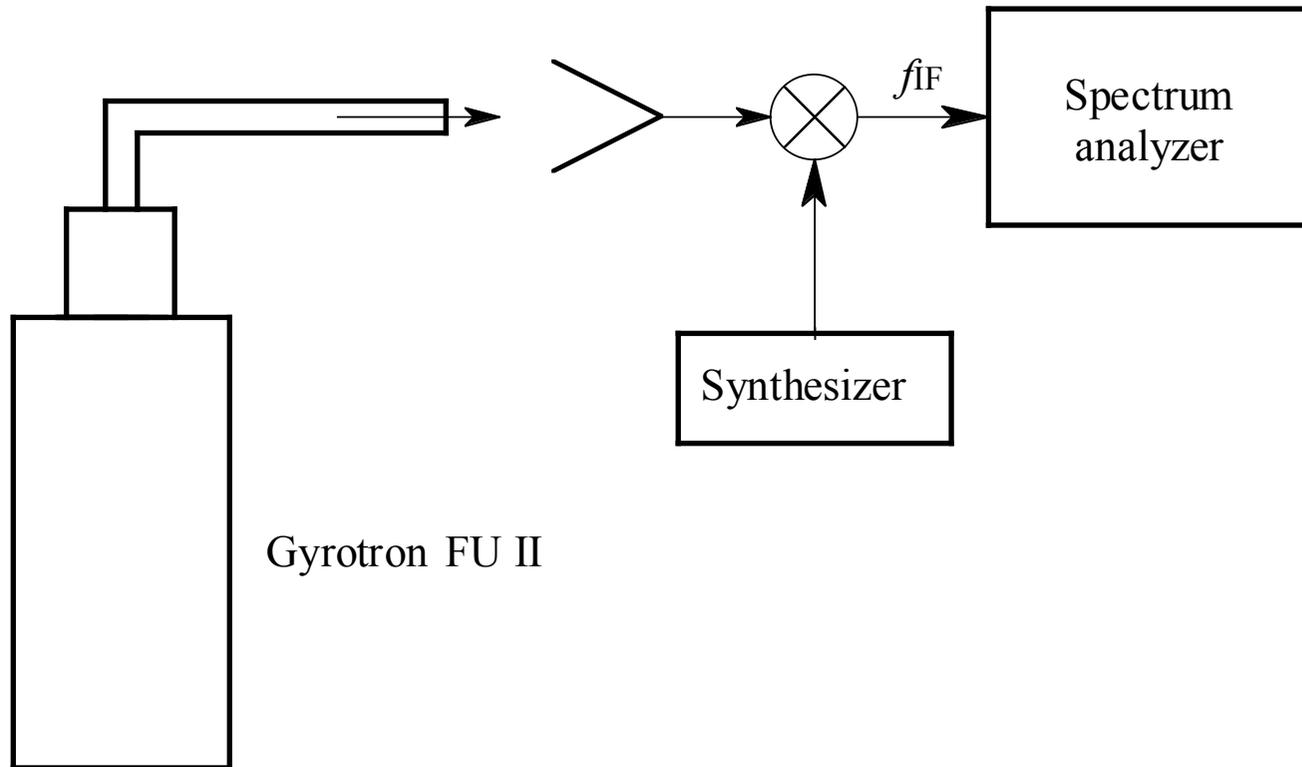
**TE<sub>16</sub> mode,  $f=354$  GHz,  $B_0 = 6.51$  T**

**$V_k = -20.0$  kV,  $I_k = 260$  mA**

**$\Delta V_k=0.5$ V,  $\Delta P/P=2\%$**



**Frequency measurement**

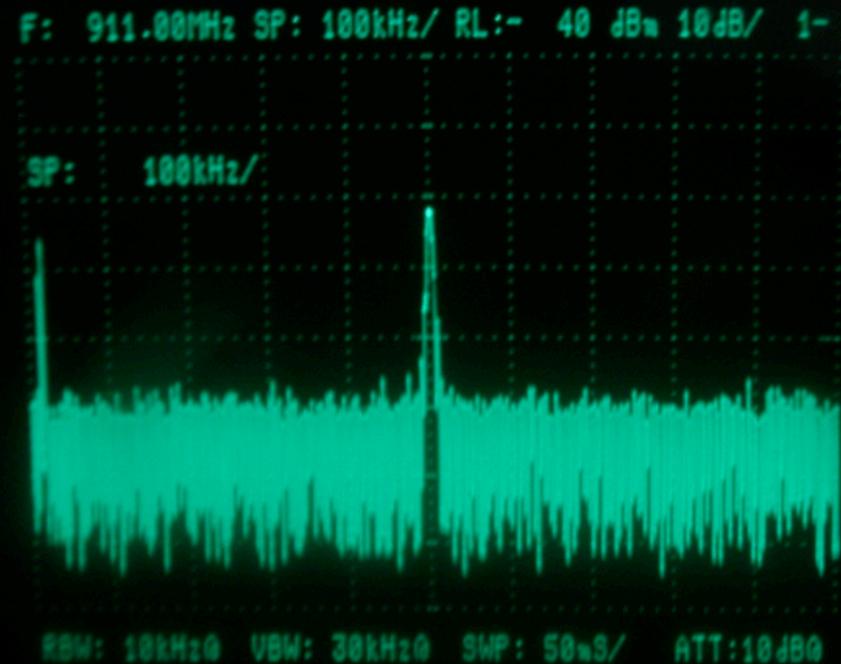


## Without a smoothing circuit

$V_k = -19.5\text{kV}$ ,  $I_k = 80\text{mA}$   
 $f = 166.77\text{GHz}$ ,  $f_L = 18.57\text{GHz}$   
 Line width  $\Delta f = 100\text{kHz}$   
 Frequency drift  $\delta f = 500\text{kHz}$

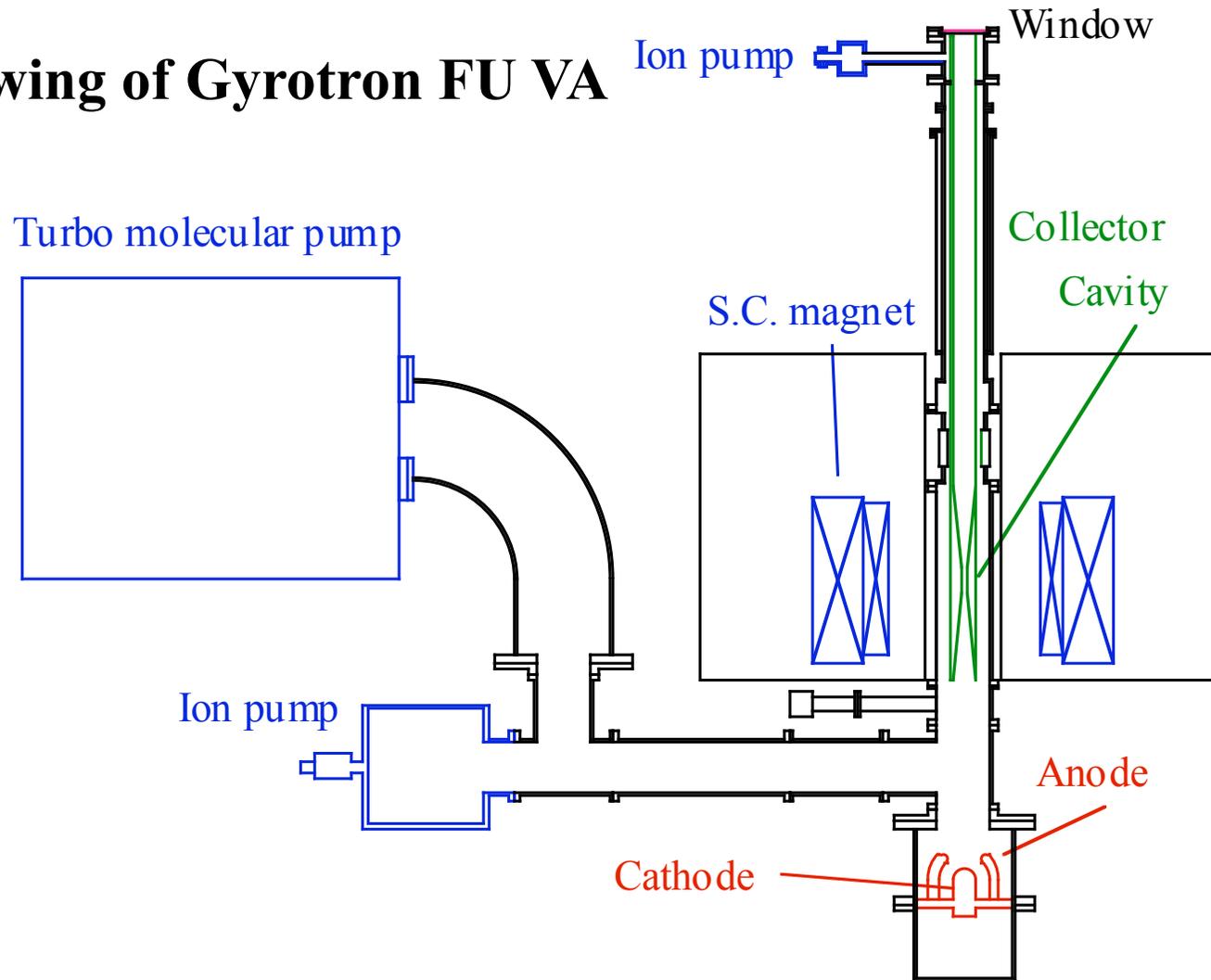
## With a smoothing circuit

$V_k = -19.5\text{kV}$ ,  $I_k = 100\text{mA}$   
 $f = 166.78\text{GHz}$ ,  $f_L = 18.43\text{GHz}$   
 Line width  $\Delta f = 10\text{kHz}$   
 Frequency drift  $\delta f = 20\text{kHz}$

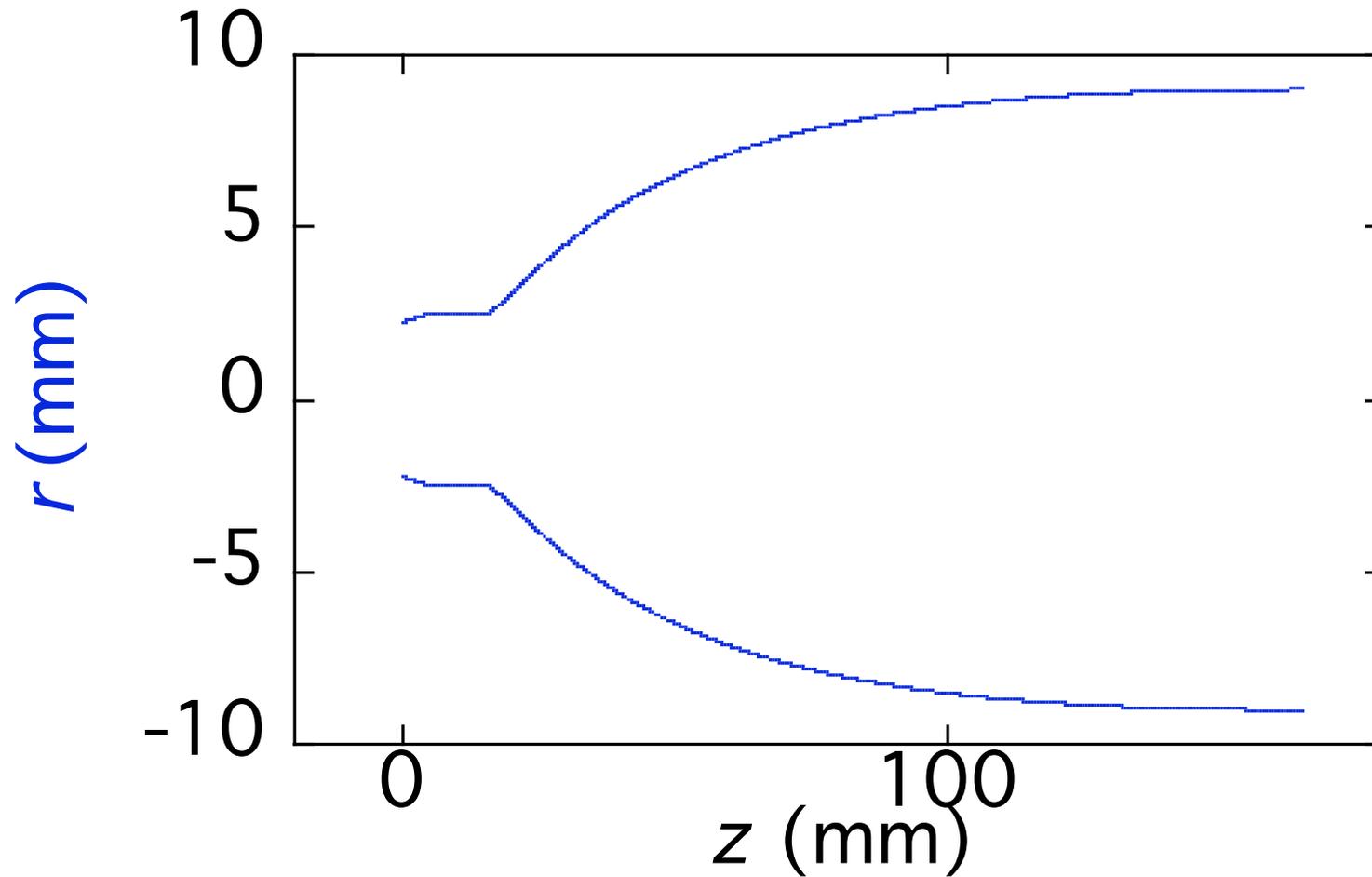


**Conversion of high mode purity output into Gaussian beam**

**A schematic drawing of Gyrotron FU VA**



## The shape of cavity and up-taper

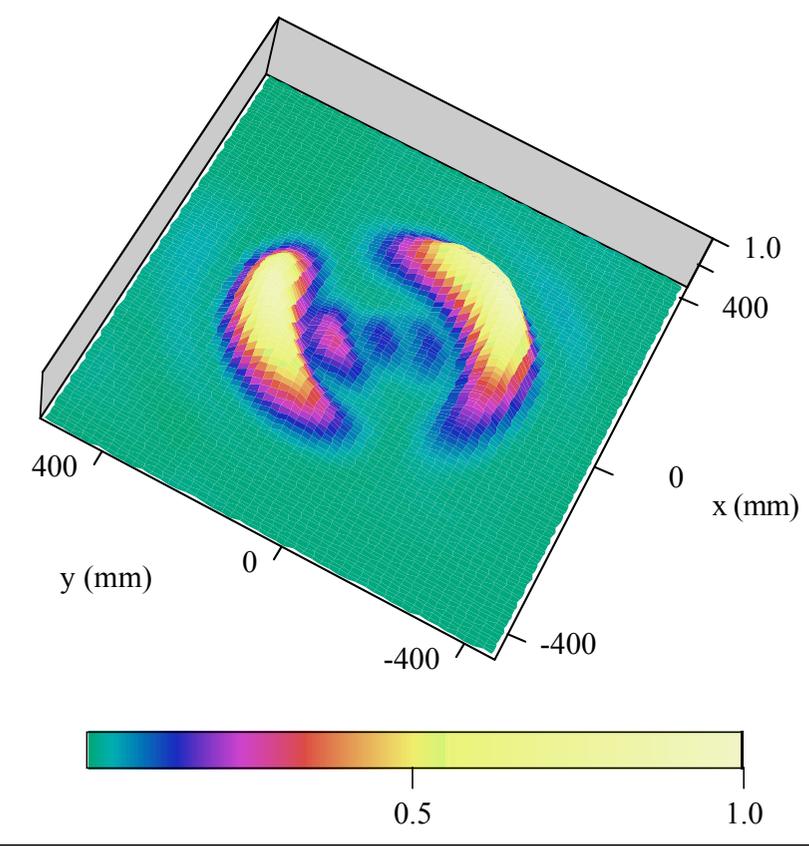
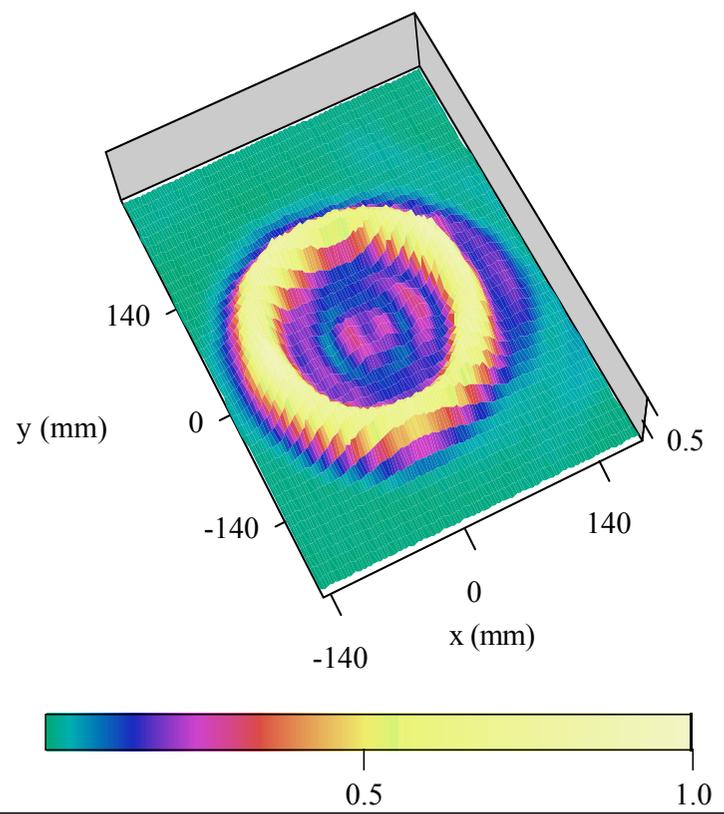


**Resonance frequencies  $f_{\text{res}}$ , diffractive quality factors  $Q_D$  and output mode purities  $\eta$  for the complete Gyrotron**

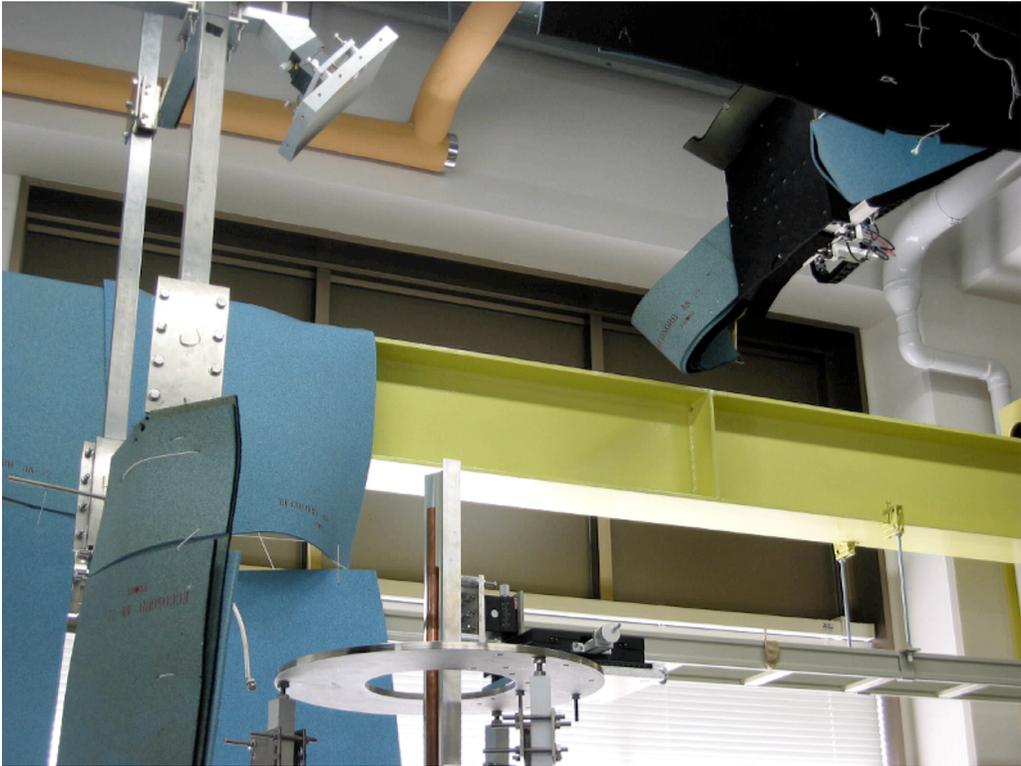
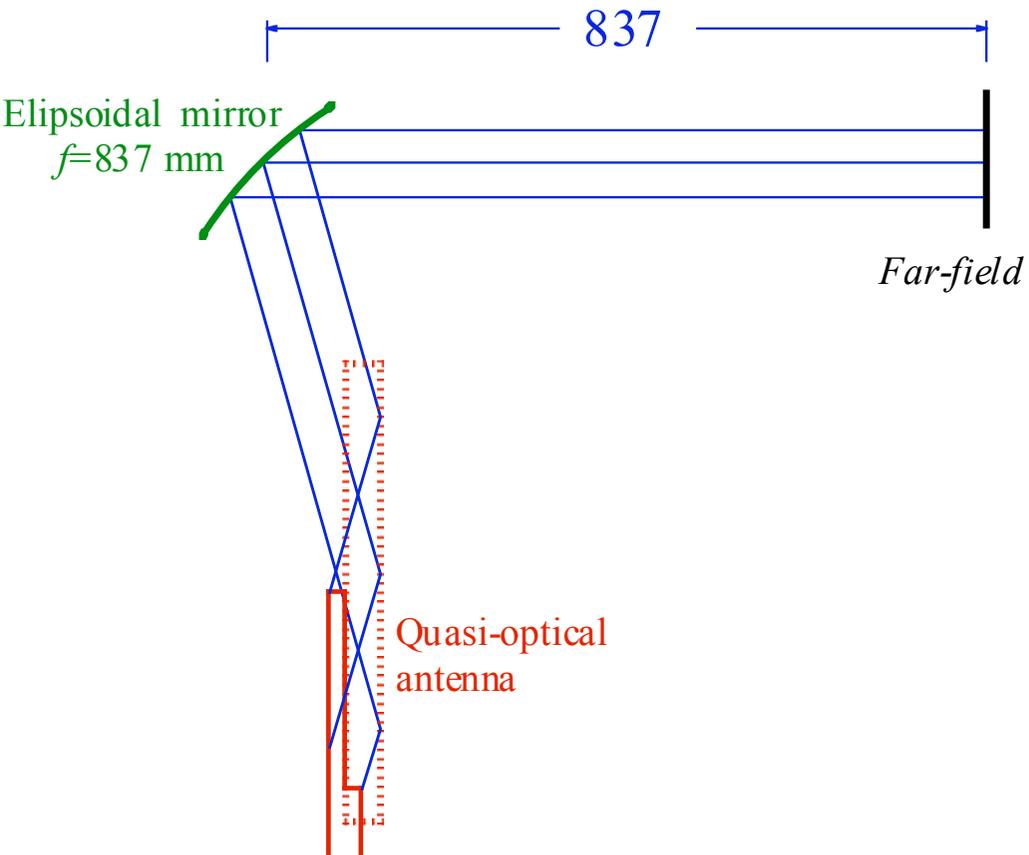
mode	$f_{\text{res}}$ (GHz)	$Q_D$	$\eta$
<b>TE<sub>01</sub></b>	<b>73.85</b>	<b>249</b>	<b>99.37</b>
<b>TE<sub>12</sub></b>	<b>102.36</b>	<b>988</b>	<b>96.25</b>
<b>TE<sub>02</sub></b>	<b>134.40</b>	<b>2917</b>	<b>97.16</b>
<b>TE<sub>13</sub></b>	<b>163.37</b>	<b>3129</b>	<b>93.97</b>
<b>TE<sub>03</sub></b>	<b>194.57</b>	<b>2568</b>	<b>93.62</b>
<b>TE<sub>04</sub></b>	<b>254.63</b>	<b>11683</b>	<b>94.49</b>
<b>TE<sub>16</sub></b>	<b>344.13</b>	<b>15670</b>	<b>94.10</b>
<b>TE<sub>06</sub></b>	<b>374.65</b>	<b>108533</b>	<b>93.50</b>

**TE<sub>03</sub> mode ( $f=194$  GHz),  $z=350$  mm**

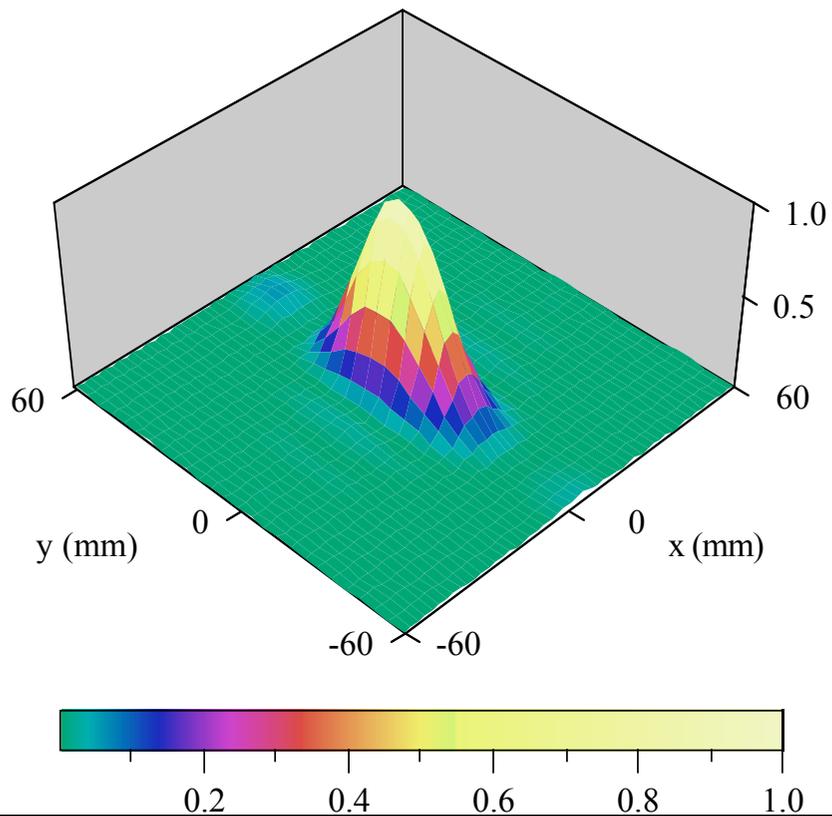
**TE<sub>13</sub> mode ( $f=163$  GHz),  $z=730$  mm**



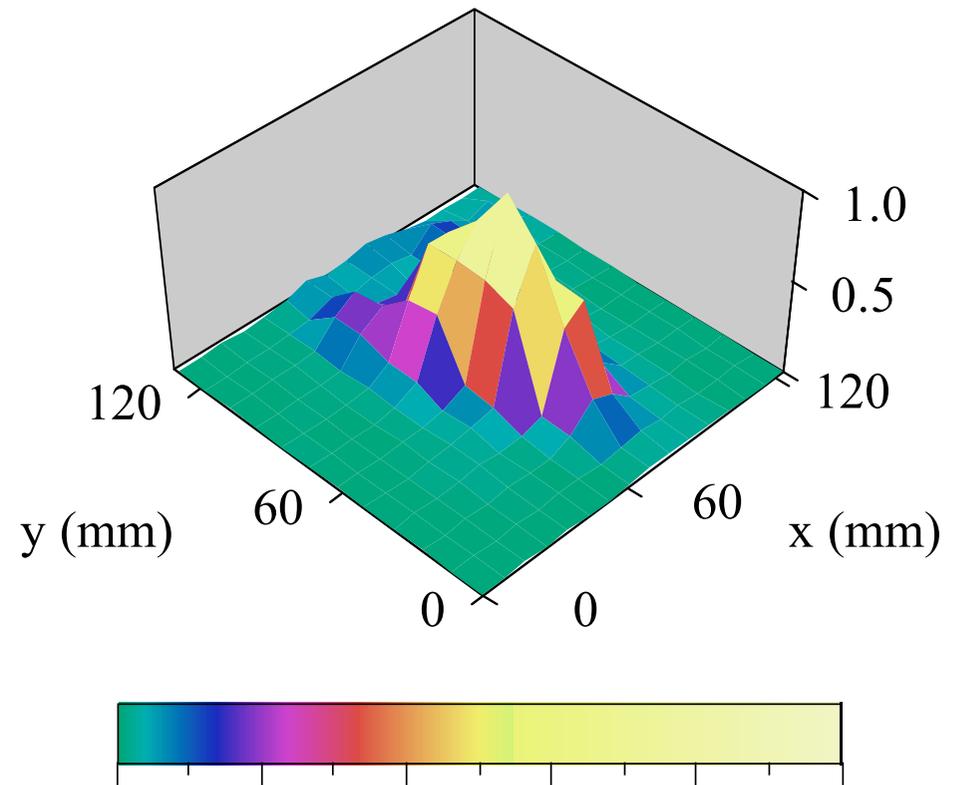
**Conversion into a Gaussian beam**



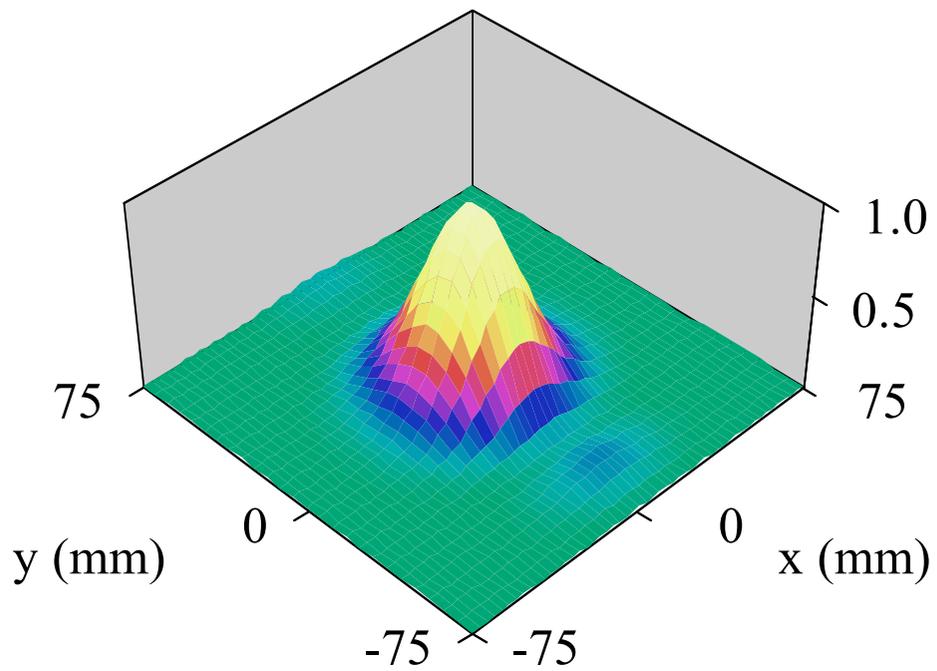
### Calculated radiation pattern (TE<sub>03</sub> mode, $f=194$ GHz)



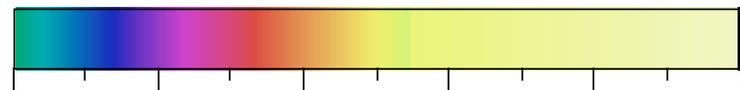
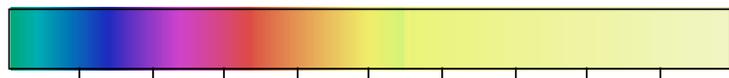
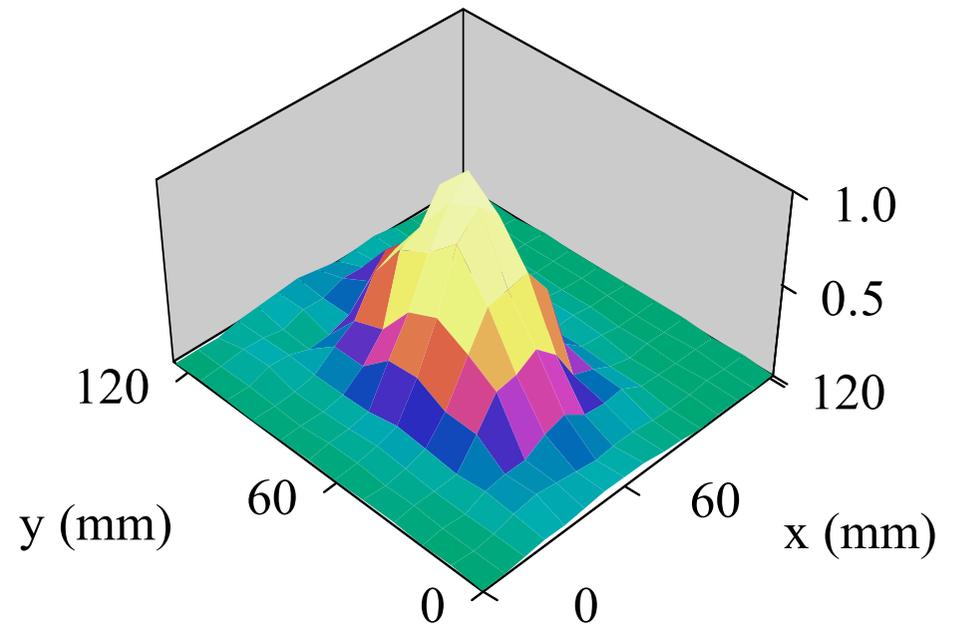
### Measured radiation pattern



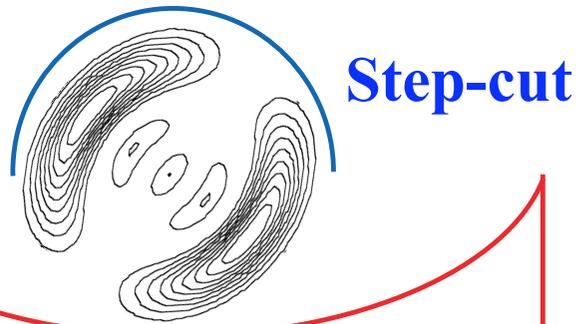
### Calculated radiation pattern (TE<sub>13</sub> mode, $f=163$ GHz)



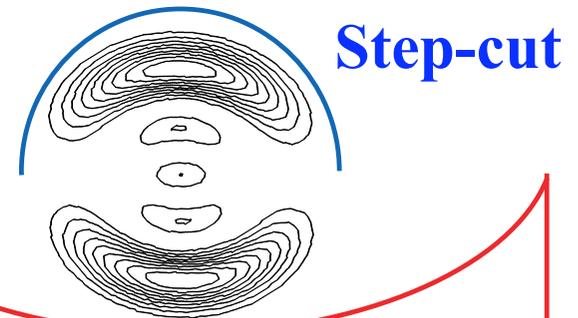
### Measured radiation pattern



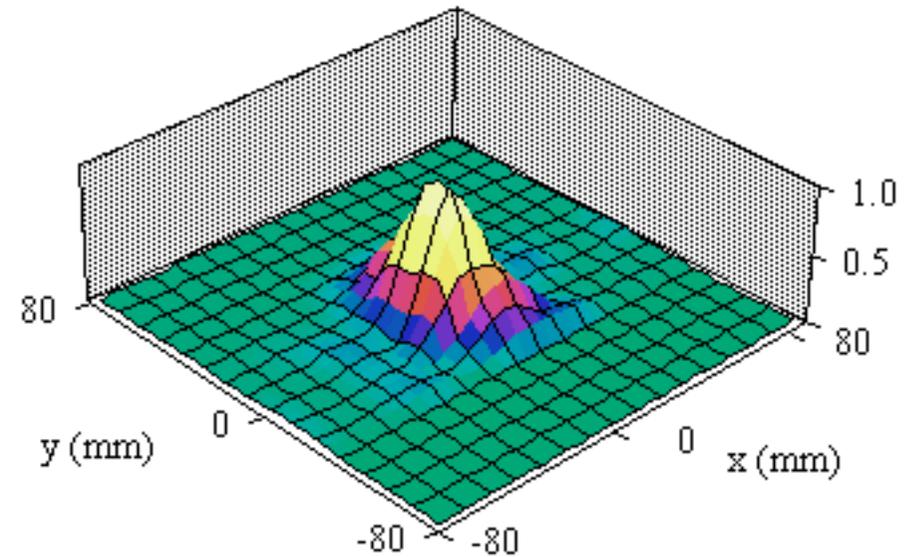
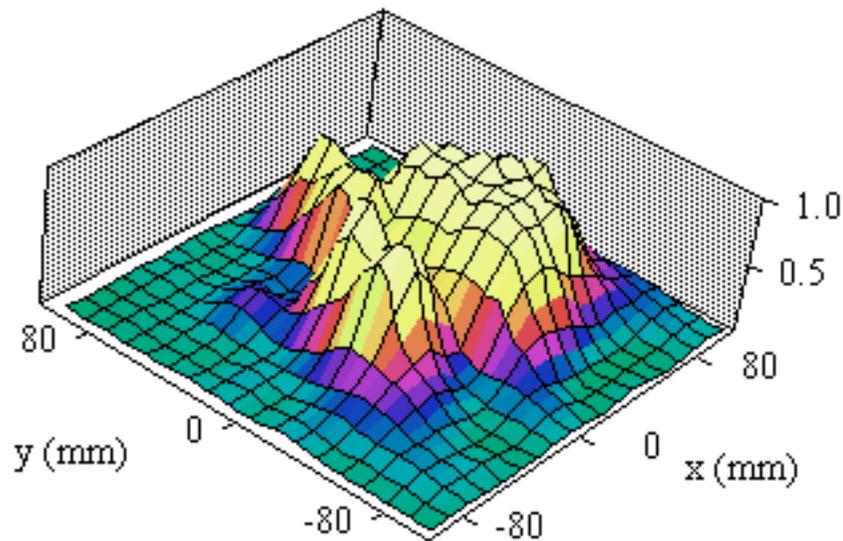
## Adjustment of quasi-optical antenna for $TE_{1n}$ mode



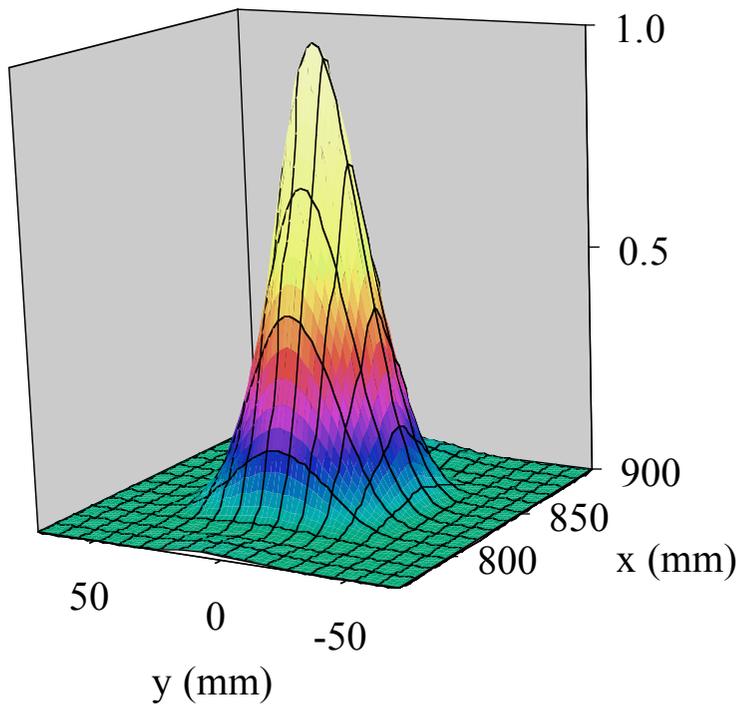
**Parabolic reflector**



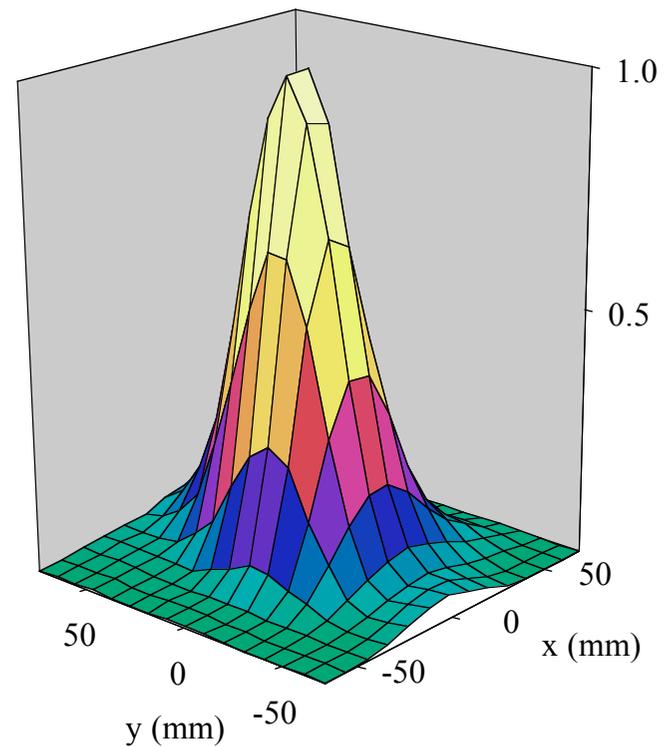
**Parabolic reflector**



**Calculated radiation pattern  
(TE<sub>13</sub> mode,  $f=163$  GHz)**



**Measured radiation pattern**



## Summary

### ● Stabilization of gyrotron output

By introducing a smoothing circuit, the ripple voltage of power supply output was reduced from 40V to 0.5V and gyrotron output power was stabilized from 10% to 2% and output frequency was also stabilized from 100kHz to 10kHz. This results corresponds to TE<sub>13</sub> mode output ( $f \sim 165$ GHz). In near future, we will prepare heterodyne system available for 354GHz and will obtain the results for TE<sub>16</sub> mode output.

### ● Conversion of high mode purity output into Gaussian beam

High mode purity outputs produced by Gyrotron FU VA were converted into Gaussian-like beams with quasi-optical system.

### In near future

- ◆ We will try to convert gyrotron TE<sub>16</sub> mode output into Gaussian beam and to couple with HE<sub>11</sub> corrugated waveguide.