

Measurement of HE_{11} -mode Radiation Pattern from 1.25 inch Corrugated Waveguide for **KSTAR ECH System***

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POSTECH

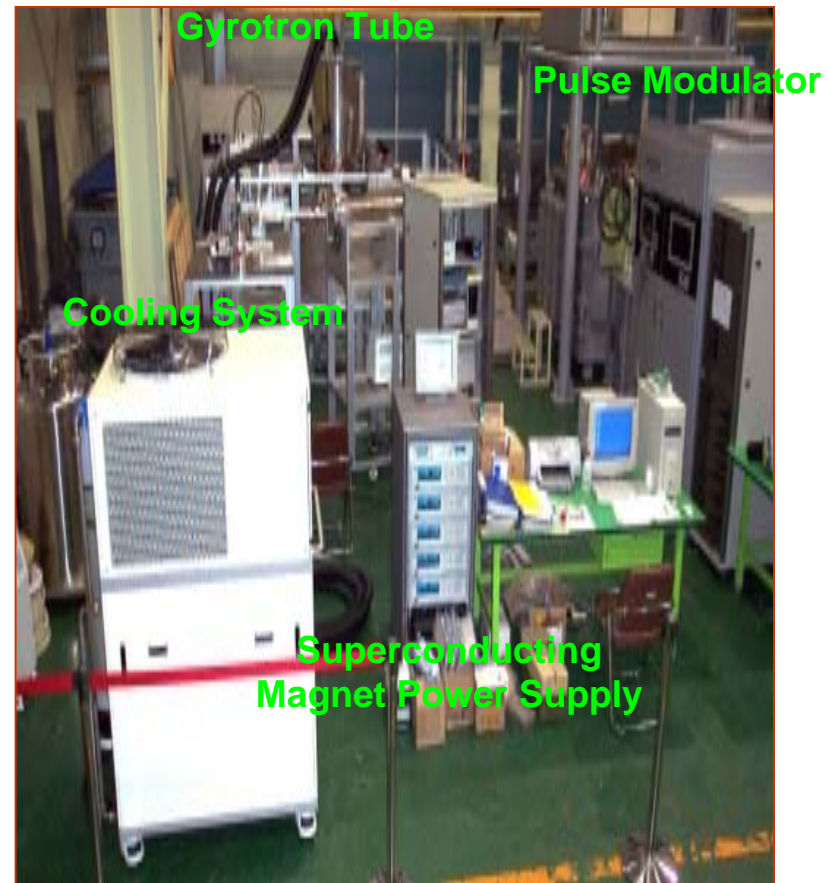
이용운, 김용태
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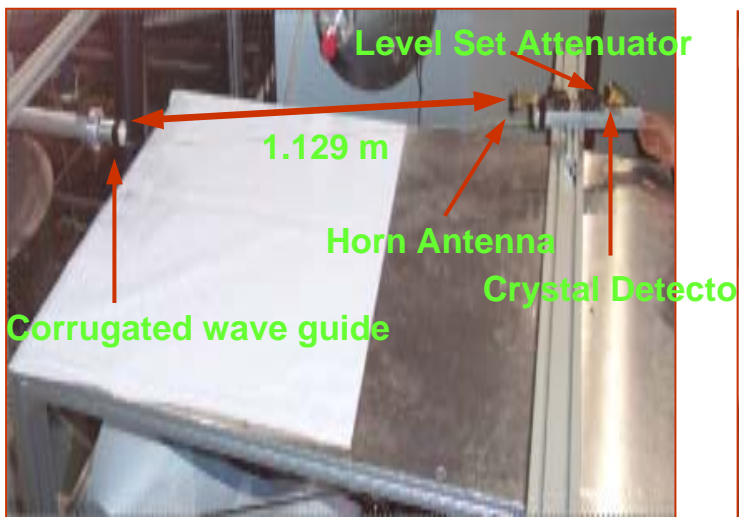
Abstract

KSTAR ECH System의 Microwave source로 84-GHz, 500 kW(출력 펄스폭: 2 sec)급의 Gyrotron tube(VGB-8084) test station을 구축하였다. Gyrotron tube 시험 운전에는 1.6 MW (80 kV x 20 A)급 PFN방식의 Modulator (Pulse width 20 μ sec)가 사용되었다. KSTAR ECH System의 RF beam 전송선은 1.25 inch corrugated waveguide로 구성되며, RF beam의 propagation mode는 HE_{11} -mode이다. HE_{11} -mode로 전파할 경우 corrugated waveguide의 끝에서 방사되는 Radiation pattern의 main lobe는 진행방향으로 형성된다. 일반적인 HE_{11} -mode의 radiation pattern을 이론적으로 계산하였고 실험적으로 측정한 결과를 비교, 분석하였다. Radiation pattern 측정은 1.25 inch corrugated waveguide끝에서 20 μ s RF pulse를 공기중으로 방사 시켜 WR10 size의 Horn antenna와 crystal detector를 이용하여 2차원 측정을 하였다.

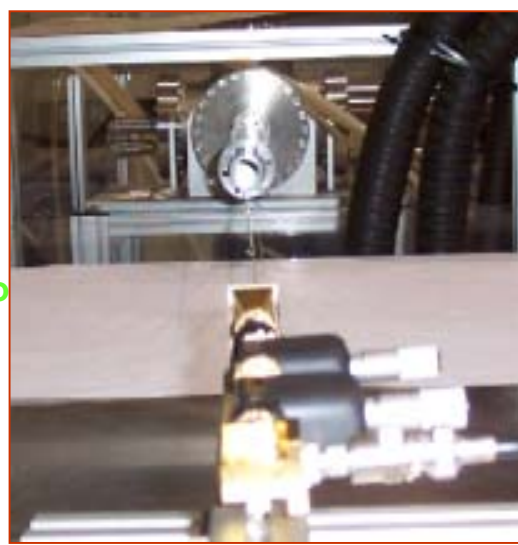
Gyrotron Test Setup



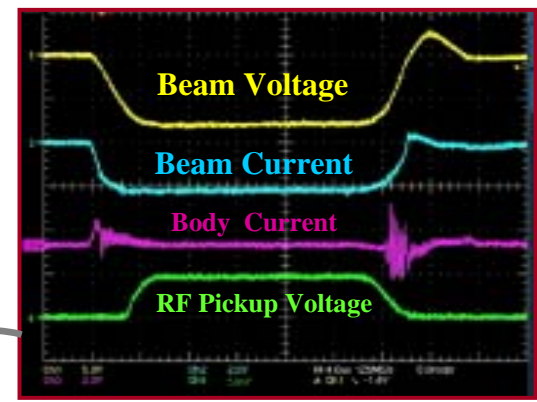
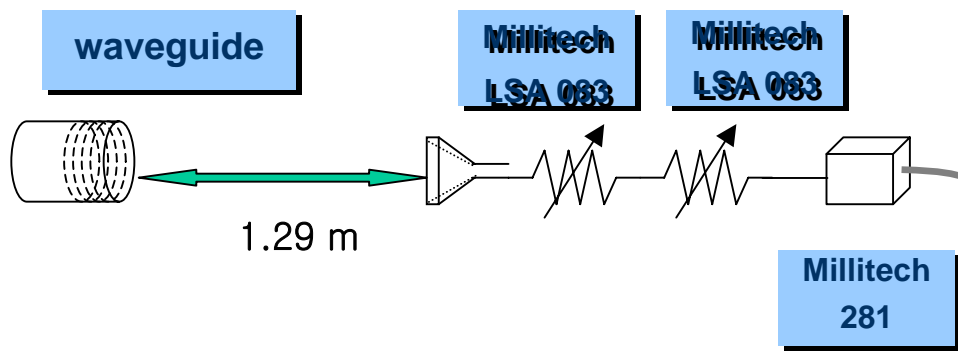
Gyrotron Radiation Pattern Measurement



Displacement of Horn antenna

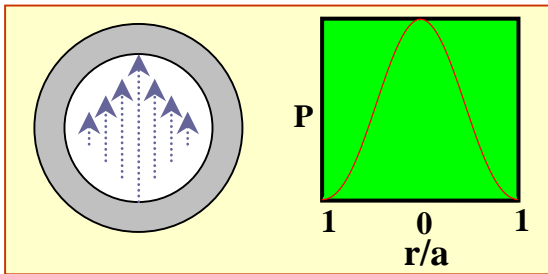


Displacement
 $\Rightarrow 4D^2/\lambda$, $D=1.25$ inch
 $= 4D^2 * f/c$,
 $f=84\text{GHz}$, $c=3 \times 10^{10}\text{cm}$
 $\approx 112.9\text{cm}$



HE₁₁ Mode in a Waveguide

Electric field shape and power distribution of HE₁₁ mode



$$E_y = E_r \sin\theta + E_\theta \cos\theta$$

$$= -\frac{ik}{\kappa} N J_0(kr) [\sin^2\theta + \cos^2\theta]$$

$$= -\frac{ik}{\kappa} N J_0(kr)$$

$$E_x = E_r \cos\theta - E_\theta \sin\theta = 0$$

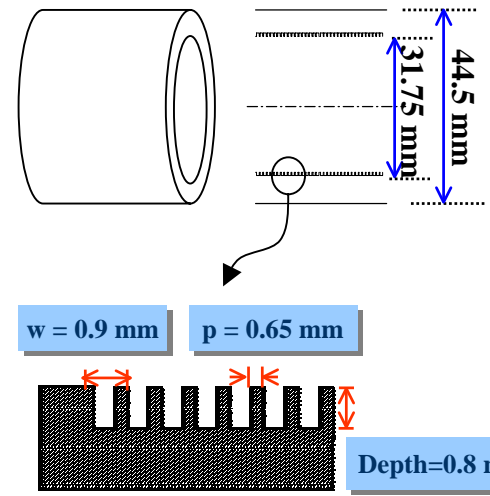
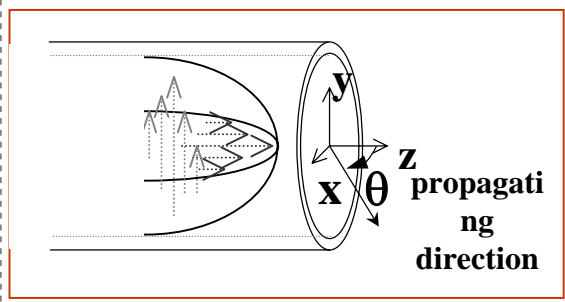
The far-field components E_ψ and E_φ at a distant point P (R, ψ, φ) from the annular aperture of width dρ and radius ρ are as follows:

$$E_\psi = \frac{j^{m+1}}{2R} e^{-jkR} E_\psi(\nu) \sin m\phi$$

$$E_\phi = \frac{j^{m+1}}{2R} e^{-jkR} E_\phi(\nu) \cos m\phi$$

Radiation Pattern of HE₁₁ Mode

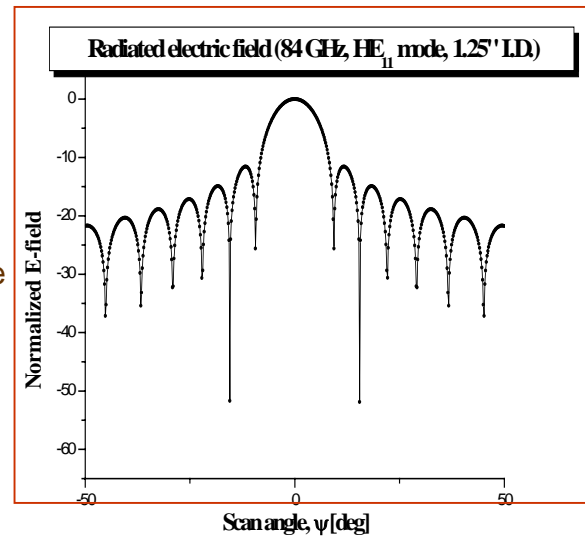
Radiated power distribution from open-ended corrugated waveguide Normalized by the P(θ=0)



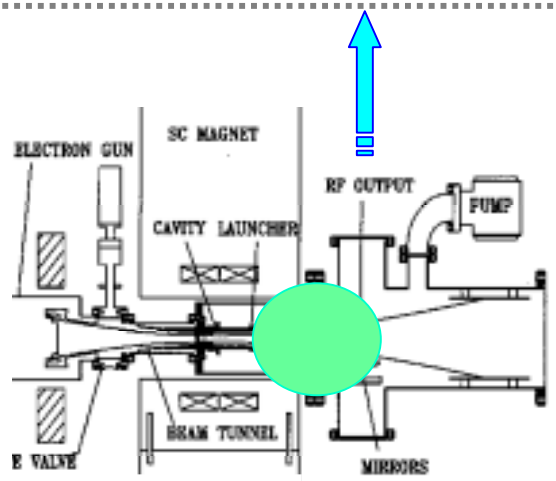
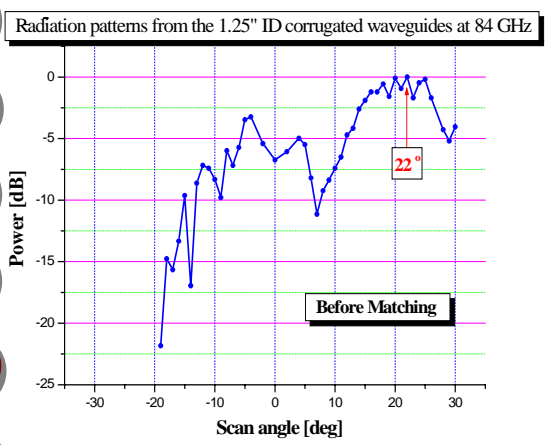
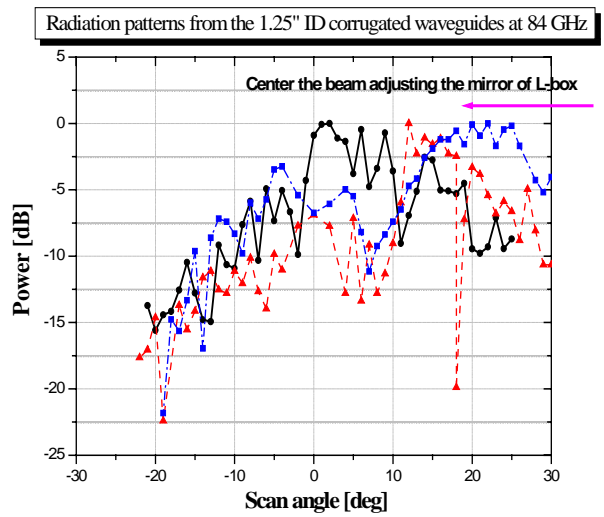
Radiation pattern of HE₁₁ mode at 84 GHz from open-ended corrugated waveguides of the diameters of 31.75 mm

The angle of the main lobe is inverse proportional to the diameter of the waveguide. Half angle of the power lobe is 5.67 degree for 31.75 mm.

The larger diameter of the waveguide is better for local power deposition.



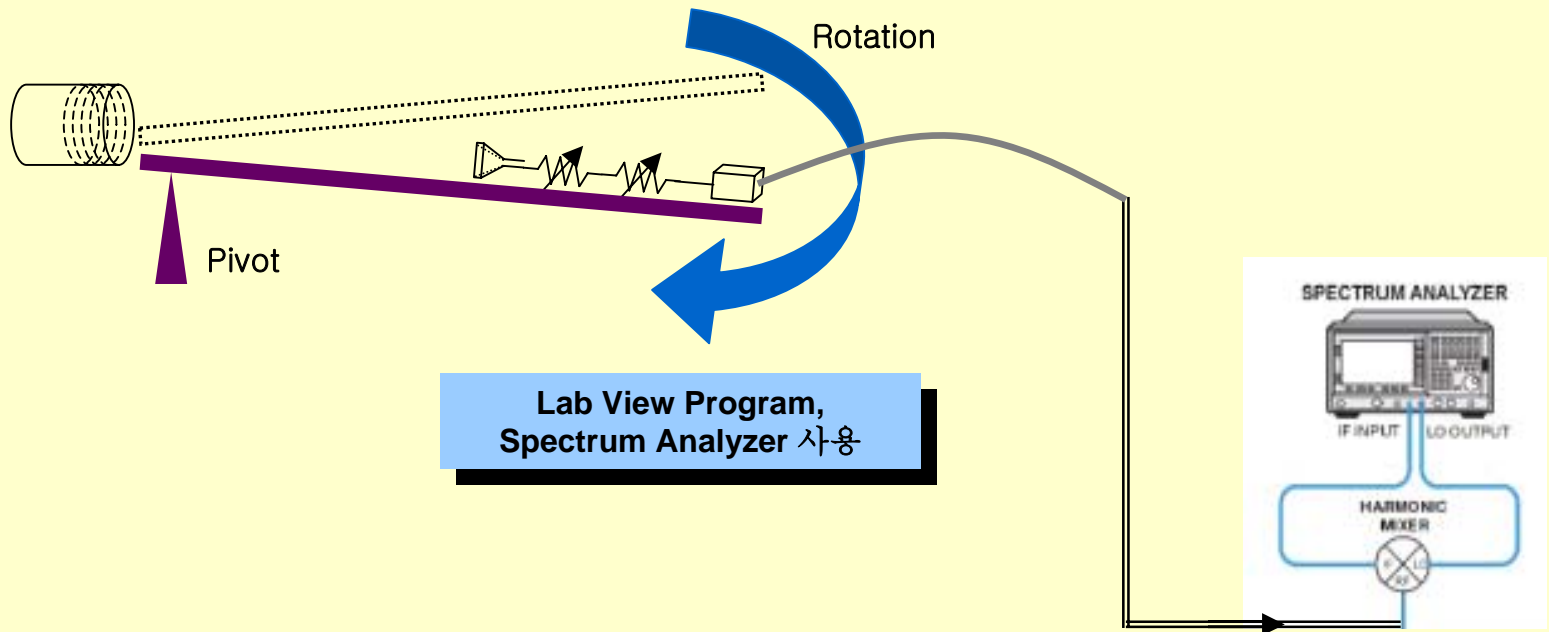
Beam Propagation



Conclusion

1. Corrugated 도파관에서 전파하는 RF Power 분포가 Gaussian 분포 임을 확인하였다.
2. Mirror에 의한 광학적 Focusing으로 Beam의 Lobe가 줄어든 것을 확인하였다.
3. RF Output Frequency 측정은 Spectrum Analyzer를 사용하여 84.14 GHz를 확인하였다.

Future Experiment



1. 0~ π 구간의 Radiation을 모두 측정한다.
2. RF beam은 Pulse 때 마다 그 특성이 다르므로 one pulse(2 sec)이내에 0~ π 까지 sweep할 수 있도록 Motor를 이용한 Pivot을 사용한다.
3. Lab View Program과 Spectrum analyzer를 이용하여 Beam의 Relativistic Power를 정확히 측정한다.