§7. System of Direction-Finding Mirror with Off-central Positioned Four Couplers

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To measure the transmitted power in the line, the waveguide coupler has been widely used in ECH experiments. The waveguide coupler consists of the fundamental waveguide below the mirror surface, which are coupled to waveguide field through a small hole array. Since the coupling efficiency depends on the incident angle α, this waveguide coupler center-positioned at the reflector is one of candidates to find effectively the incident angle and to align precisely the optical-axis. However, since the dependence of the coupling efficiency on α is not so strong. To find the incident angle or to align the transmission line, the direction-finding mirror system with off-central positioned four couplers is developed and is demonstrated in the low power test. Here, the four couplers are labeled as +X, -X, +Y, -Y which are off-central positioned in the x and y directions at the reflector plane. The well-defined Gaussian beam is injected to the mirror with the incident angle α=45 degrees. The mirror is shifted in the x and y directions to take the spatial dependencies of the intensity and phase detected at the $\pm$X and $\pm$Y couplers. Figures 1 (a) and(b) show the spatial dependencies of the detected intensity and phase in the low power test[1)]. The differences of the intensities at the $\pm$ couplers in the x and y directions are also shown in the figure. In taking each difference, the intensity is normalized by the maximum. The beam centeral positions in the x and y directions are 0.3 and 2.6mm, while the null positions at the differences in the x and y directions are 5.0 and 1.5mm, respectively. The larger error is 4.7mm, but that is within the tolerable limit. Using the intensities detected with the couplers, it is confirmed that the method is available as the spatial alignment of the mirror.

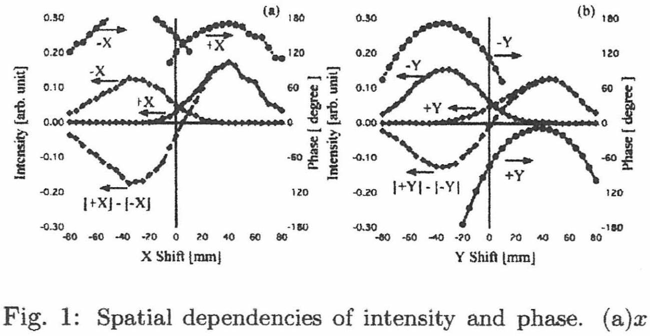

Fig. 1: Spatial dependencies of intensity and phase. (a)x and (b)y directions.

Figures 2 (a) and (b) show the dependencies of the intensity and phase detected with the X and Y couplers on the incident angle, respectively. The incident angle is scanned by rotating the mirror with the couplers around the y axis. The phase at the X couplers is varying nearly proportional to the rotation or incident angle, and then is a robust measure for the incident angle. The propagating z position until the X coupler is changed as the term of $d_x \sin\alpha$ by the rotation, where d_x is the distance between the center of the reflector and each X coupler. The phase should be proportional with the slope of $kd_x \sin\alpha$, provided that $d_x \gg R_x$. The quantities k and R_x are the wavenumber of the incident beam and the phase curvature in the x direction, respectively. It should be noted that the phase variations are negligibly small at the Y couplers. The independent angular alignments in the x and y directions are confirmed to be available by the test.

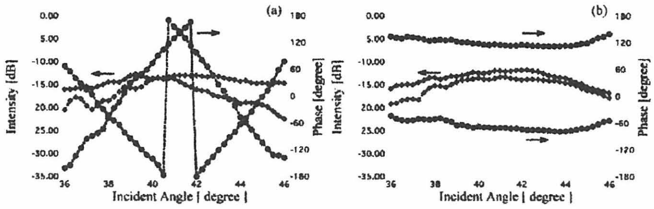

Fig. 2: Angular dependencies of intensity and phase in (a):x and (b):y directions

To detect the phase difference between the couplers in the interferometic measurement, both outputs from the X and Y couplers are introduced into additional directional couplers. The intensities to be mixed are adjusted with the additional level-set attenuators. The interferometer signal using the X couplers is plotted as a function of the incident angle in Fig.3. There are a few sharp drops in the intensity dependence on the incident angle. This dependence on the incident angle is due to the variation of the phase difference at the couplers by the rotation. The dynamic range in the drop is about 15dB. This sharp drop allows to set reproducibly the angle with a precision better than $\pm$0.2 degree. It is also indicated that the phase jumps of 180 degrees near interference minima, which are characteristic for an interferometer.

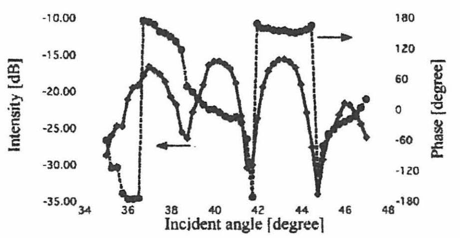

Fig. 3: Intensity and phase in interferometer signal.

Reference
1) Idei, H., *et al.* Proc. of 26th IRMMW Conf. (2001).