# MBI: Millimetre-Wave Bolometric Interferometer

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**Abstract.** We present the design of the prototype of a millimetre-wave bolometeric interferometer (MBI). This interferometer uses two arrays bolometers as detectors. The combination of high sensitivity bolometers and interferometric imaging appears to be well suited for precision measurements in observational cosmology.

## INTRODUCTION

We describe a new instrument for observations of faint astrophysical sources at millimeter and sub-millimeter wavelengths: an interferometer, which uses sensitive bolometers as detectors. An interferometer has multiple advantages over a single telescope system, such as:

- Direct measurement of the Fourier transform (visibility) of the sky brightness in 2-D
- Reduced effects of atmospheric fluctuations in ground-based observations
- High angular resolution without large, expensive single dish
- Rapid mechanical chopping not required
- Bolometers time constants can be long and
- Reduced side-lobe pickup.

We are building an instrument to exploit these advantages of interferometry to image the CMB polarization [4], image the S-Z effects in clusters of galaxies [1,3] and also to look for primordial galaxies [2] at sub-mm wavelengths.

## INSTRUMENT

### Two Element Interferometer

In a simple 2-element radio interferometer, signals from two telescopes aimed at the same point in the sky are multiplied (correlated) so that the sky temperature is sampled with an interference pattern with a single spatial frequency. The output of the multiplying interferometer is the visibility. To recover the full phase information, complex correlators are used to measure simultaneously both the in-phase and quadrature phase components of the visibility. In an interferometer that uses incoherent detectors, such as an optical interferometer, the electric field wavefronts from two telescopes are added and then squared in a detector (an "adding" interferometer as opposed to a "multiplying" interferometer [5]). The result is a constant term proportional to the intensity plus an interference term. The constant term is an offset that we propose to remove by modulating the length of the baseline D by a few wavelengths at a frequency of ~1 Hz. Phase-sensitive detection at this modulation frequency recovers both the in-phase and quadrature phase interference terms and reduces susceptibility to low-frequency drifts (1/f noise) in the bolometer and readout electronics. We recover the same visibility as for the multiplying interferometer.

CP616, *Experimental Cosmology at Millimetre Wavelengths, 2K1BC Workshop,* edited by M. De Petris and M. Gervasi

## 2-Element Prototype Interferometer

The baseline of the prototype MBI is formed by two identical flat mirrors, which direct their beams to two Cassegrain telescopes. The telescopes couple the beams from the flat mirrors to a cryogenic beam combiner and detector system housed inside a 4K cryostat. The detector system includes two separate 9 pixel bolometric arrays. The detectors are spider-web bolometers cooled to ~ 280 mK by $^3$He refrigerator.

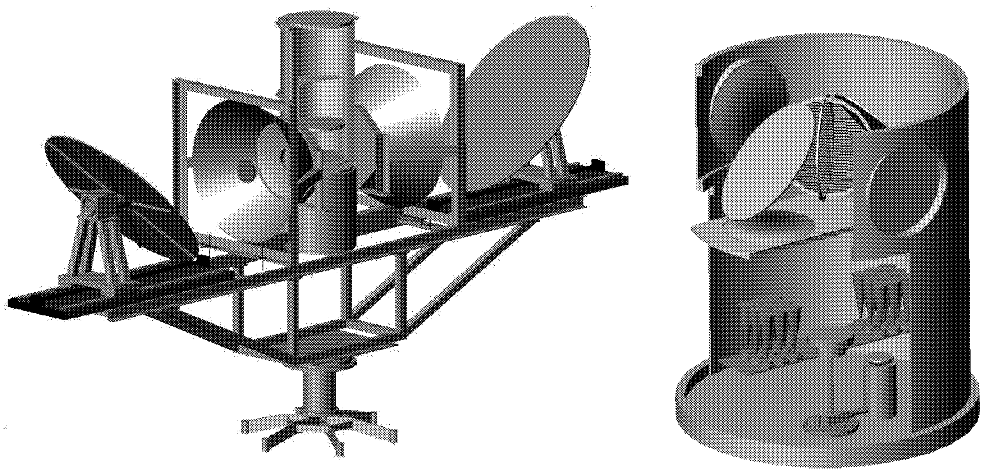

*Figure 1.* Prototype 2-element interferometer. Two flat mirrors form the baseline, which can be varied from 1 to 4 meters. Wave fronts reflected from these two mirrors are directed to small (0.5 m diameter) telescopes attached to a cryostat, which houses cold optics and the detectors. The figure on the right shows the details of the quasi-optical beam-combiner and the bolometric detector arrays. Two crossed polarizers, constructed from a lithograph of 0.2 micron thick copper wires on a poly-propylene substrate, form the beam-splitter.

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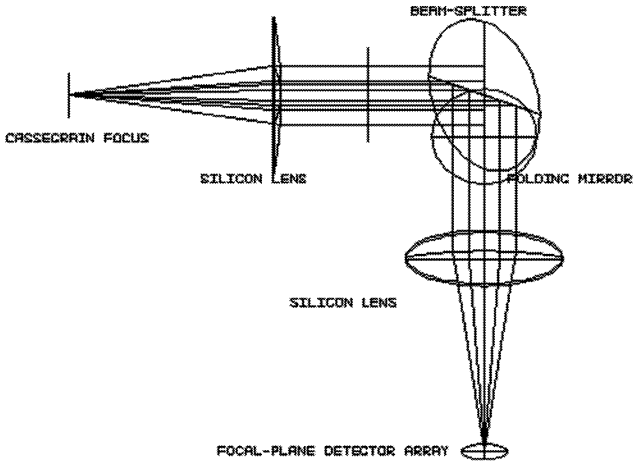

**FIGURE 2.** Schematic of one arm of the interferometer: the Cassegrain telescope and the beam-combiner. The incoming beam is collimated by the first silicon lens on to the orthogonal metal grid beam splitters. The vertical and horizontal beam splitters reflect and transmit the horizontally and vertically polarized component of the beam respectively, which comes from one arm of the interferometer, and mix with the corresponding component of the incoming beam from the other arm. After interference the resulting beam is directed towards the detector array by the folding mirror and another silicon lens. For clarity only the central pixel is shown.

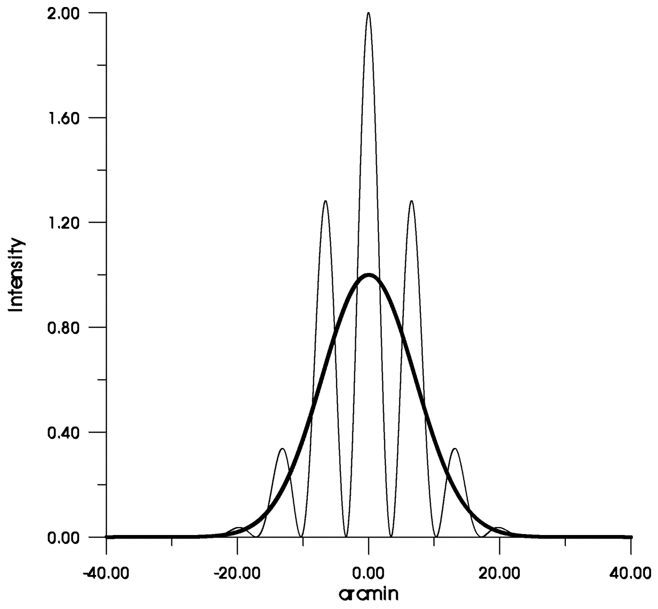

**FIGURE 3.** Simulated Gaussian beam response of a single 50 cm diameter antenna element working at 2 mm wavelength. Superimposed is the interferometer fringe pattern produced by a single baseline of 1 metre. By moving one of the flat mirrors back and forth +/- 3 λ (corresponding to +/- 6mm) – the whole complex visibility function can then be measured. The Fourier Transform of the complex visibility function gives a map of the sky brightness.

If the bolometers detect a single at 2 mm wavelength with a bandwidth of $\Delta\nu$ = 20% and optical efficiency 0.3, we estimate the sensitivity of each bolometer to be NET ≈ 370 μK/√Hz. For MBI with two 9-bolometer arrays we expect 5 mK·√s. noise per pixel in the synthesized image. For a good site we estimate that approximately 37 days are needed to integrate an image of 324 pixels down to 3 μK noise per pixel. This performance is comparable to a filled aperture 6 m telescope.

## CONCLUSION

We plan to test the prototype in Tenerife by April 2002 and later take the interferometer to better observing sites, e.g. South Pole for future campaigns. Later we propose to build a 3-element longer baseline interferometer so we can probe more points in the uv plane simultaneously and can achieve higher angular resolution.

## REFERENCES

1. Birkinshaw, M. "The Sunyaev-Zel'dovich Effect," in *AIP Conf. Proc.* 476: 3K cosmology, 1999, pp 298.
2. Bond, J. R., Carr, B. J., and Hogan, C. J., *ApJ*, **306**, 428 (1986).
3. Carlstrom, J. E., Joy, M., and Grego, L., *Ap.J*, **456**, L75, (1996).
4. Hu, W. and White, M., *New Astronomy,* **2**, 323, (1997).
5. Rohlfs, K. and Wilson, T. L., **Tools of Radio Astronomy**, 2d ed., Springer, New York, 1996.