Introduction

Microspec (μ-Spec) is a direct-detection spectrometer which integrates all the components of a diffraction-grating spectrometer onto a 400-μm × 550-μm chip through the use of superconducting microstrip transmission lines on a single-crystal silicon substrate.

The second generation of μ-Spec was designed and is currently being built to operate with a spectral resolution of 512 over a 714-555 μm (420-540 GHz) wavelength range, a band of interest for NASA’s Experiment for Cryogenic Large-Aperture Intensity Mapping (EXCLAIM).

μ-Spec differs from similar technologies.

- In a Rowland spectrometer, the required phase retardation is generated by reflection from the grating grooves.

- In Z-Spec, propagation occurs in parallel-plate waveguides [1], which remains a bulky option (56-cm length scale and 4-kg mass).

- Bootlace lenses are a 1-dimensional analog of Z-Spec [4], which μ-Spec builds on for submillimeter wave applications.

- Narrow-band filter-band spectrometers do not rely on optical interference as in grating or Fabry-Perot spectrometers. Some examples are: SuperSpec [5], figure below), the Delft SRON High-redshift Wapper (DESHIMA) [6], the Chip Submillimeter Emission Surveyor (CAMELS) [7], and similar alternatives made in rectangular waveguides (e.g., W-Spec [8]).

The EXCLAIM mission

EXCLAIM is a balloon-borne telescope that will map the emission of CO ([C]) lines in redshift windows of 0-2.55. These lines are key tracers of the gas phases in the interstellar medium involved in star-formation processes.

EXCLAIM will adopt an approach called intensity mapping (IM).

- It will measure the statistics of brightness fluctuations of redshifted, cumulative line emissions instead of detecting individual galaxies.

- This enables a blind, complete census of emitting gas in cross-correlation with a high dispersive optical galaxy catalog such as the Baryon Oscillation Spectroscopic Survey (BOSS) [1].

Building on demonstrated technology

Diffractive region design methodology

An optimized geometry is found for the transmitting antennas (red arc in Fig. 4) and the delay network extra lengths in silicon (not shown) through the minimization of the root-mean-square (RMS) phase error on the spectrometer focal plane (Fig. 5) [12]. The receiving antennas (green arc in Fig. 4) are laid to Nyquist-sample the combined power beam.

The design methodology was updated from [9,13] to account for the superconductor’s kinetic inductance (KI) in the silicon dielectric. The KI fraction is determined by the medium, through which the transmission lines are made. The detrimental effects are quantified through the frequency dependence of the ratio of the phase velocity without KI to the phase velocity with KI following the Matlis-Bardeen theory [14].

References


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