P3 (GEP=4)

Title Measurements of complex dielectric constants of samples in millimeter wave bands using Martin-Puplett type Fourier Transform Spectrometer with high sensitive Millimeter-wave bolometers

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GPPU Experimental Point (GEP): 4

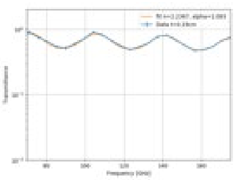
Goal of Study

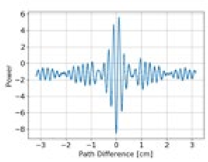
Learn following things. 1. Fundamentals and operation procedures of the Martin–Puplett type Fourier Transform Spectrometer (MP–FTS){1}. 2. Methods for measuring sensitivity and fundamentals of semiconductor bolometer detector system [2]. 3. How to make 0.28K environment with He3 sorption refrigerator. 4. Treatments of Turbomolecular Pump system and Mechanical Booster Pump system. 5. Treatments of wet dewar. 6. Data acquisition (DAQ) systems: read out circuit with operational amplifier and Labview. 7. How to measure the Frequency dependence of the complex dielectric constants of samples in millimeter wavebands using the FTS.   8. Writing data analysis codes.

Contents

MP–FTS is a broad band absolute spectrometer which has played important role in wide field of astronomy, cosmology and calibrating detector systems in the wave bands longer than far infrared wave bands. The FIRAS instrument mounted on COBE satellite[3] is one of the most famous applications of MP–FTS. It measured spectrum of the cosmic microwave background (CMB) radiation and showed that it follows the perfect black body spectrum with temperature of 2.725K. This result has confirmed that our universe has been evolved following the description of the standard big band theory. A photo of the MP–FTS which is used in this experiment is shown in right panel. MP–FTS does not lose value and is still active in observational astronomy and cosmology fields.

In this course, the application of the MP–FTS to the measurements of the frequency dependence of complex dielectric constants of samples against millimeter wave at room temperature and liquid Nitrogen temperature is experienced.   Millimeter wave high sensitive bolometer with Nitrogen Trans Doped Germanium (NTD–Ge) semiconductor thermistor is used as detector. A photo of inside of detector cryostat, which is wet dwar, is shown in left panel. Scenery of the measurement is shown in right panel. An example of the sample measurement auto–correlation fringe is shown in left panel.   An example Obtained frequency dependence of the transmittance of a sample against millimeter waves is shown in right panel. Beat signals found in the fringe and sinusoidal pattern found in the transmittance are caused by Fabry–Perot interefence effect. By fitting the transmittance, refractive index and absorption coefficient, that is real and imaginary part of dielectric constant, are obtained.





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Textbook and References

[1] MP-FTS: Martin,D.H. and Puplett,E., Infrared Phys., 10, 105 (1969)
[2] Detector: G.H.Rieke, Detection of light, Cambridge Univ. Press, 1994
[3] Application example for cosmology: J.C.Mathor et al., ApJ, 420, 439 (1994)
[4] Optics: M.Born and E.Wolf, Principles of Optics, Sections 1 and 7 (1974)

Progress Schedule

✧ Day 1

Study fundamentals and operation procedures of Semiconductor bolometers including read our circuit, He3 sorption refrigerator and MP-FTS with observing devices.

Close the cryostat.

✧ Day 2

Start pumping the cryostat with turbo pump.

Precool the cryostat using liquid Nitrogen (LN2) after it reaches high enough vacuum degree.

While waiting that the cryostat reaches high enough vacuum degree, studies principles of extracting frequency dependence of complex dielectric constants from the data obtained by FTS and sensitivities of bolometer.

✧ Day 3

Stop the precooling processes and get out LN2 from the He layer of the cryostat.

Pour liquid He4 in the cryostat.

By decreasing pressure inside of He4 layer with the Mechanical Booster pump, lower the temperature down to cooler than the boiling temperature of He3.

By manipulating the temperature controller, cool down the detector mount to 0.28K.

Acquisite data to estimate detector sensitivities.

Perform measurements to get transmittance of sample against millimeter wave at room temperature and LN2 temperature, that is 77K.

Close the measurement system.

✧ Days 4

Analyze data obtained previous day.

Submit a report of the experiment and give a brief presentation on the experiment.

Discuss future possibilities of FTS. Fundamental idea and present status of the state of art technology ‘on chip FTS’ is introduced.

Other Details

Course Period	2019 Summer
Place	Science C building N402
Number of Students	1—3
Evaluation method	The evaluation method will based on experiments (60 %), presentation (30 %), and discussion (10 %). Single report is expected to be submitted from all participant but contribution of each person must be clarified.

In Addition
