様式 2 (Form 2)

（2015 年 1 月改定）

滞在型研究員報告書
Activity Report for the NAOJ Visiting Fellows Program

所　　属 (Institution)	Observatoire de Paris
氏　　名 (Name)	Fabien Defrance
研究課題名 (Research subject)	Design of a lens for ALMA band 11 receiver
滞在期間 (Period of stay)	2016 年　08 月　02 日～　2016 年　08 月　31 日 YYYY　MM　DD　　YYYY　MM　DD
受入責任者氏名 (NAOJ host researcher)	Dr. Takafumi Kojima

１．滞在型研究員として国立天文台滞在中に行った活動について簡単にお書きください。
(Summarize your activities during the stay using the NAOJ Visiting Fellows Program.)

At ATC (Advanced Technology Center), I worked with Takafumi Kojima, Alvaro Gonzalez and Matthias Kroug on the development of ALMA band 11 receiver. Our goal in a near future is to demonstrate the heterodyne response of an SIS mixer above 1 THz, and also to investigate the mixing properties such as conversion gain and noise temperature. NAOJ plans to fabricate superconducting materials on a sapphire substrate for the terahertz SIS mixer. However, the post processing (dicing, polishing, etc.) and the device mounting technique on the sapphire substrate have not been established yet. Therefore, for the first stage, a quasioptical approach will be more reliable than using a waveguide.

To enable the testing of several mixers during the development process, a lens will be used to focus the local oscillator and RF signal onto the mixer antenna. A first mixer at 1.25 THz will be designed and tested before the development of a final mixer covering the frequency band from 1.1 THz to 1.6 THz. Therefore, this first lens has to be optimized for 1.25 THz. The first part of the work has been to choose the best shape and material for the lens. This design has been checked with FEKO, an electromagnetic simulation software, by illuminating the front of the lens with the incoming Gaussian beam. This beam was focused at the back of the lens where the mixer circuit will be positioned. Then, the dimensions of the double slot antenna of the mixer circuit were optimized for a sapphire substrate with the software HFSS. FEKO was used again to simulate the beam pattern of the optimized double slot antenna with the lens. Due to the large size of the lens and the necessity to use the Method of Moments with the antenna circuit, simulations were using a lot of memory (>100 GB) and it was impossible to keep the sapphire substrate and the anti-reflective coating in the simulation model.

Therefore, the first design has been completed during the stay. However, in order to obtain better performance, I will collaboratively continue to work on the optimization of the design. In a near future, NAOJ will manufacture the lens based on this design, and fabricate the SIS mixer.

２．今回滞在型研究員として得られた成果について簡単にお書きください。
(Summarize your research products from the stay.)

During the stay at NAOJ, I calculated the shape, size and material of the lens in order to optimize its efficiency. The hyperhemispherical shape was chosen because of its high Gaussicity and because it couples well with the converging incoming beam produced by an ellipsoidal mirror, already present in the quasi-optical system. The lens will be made of silicon because of its very low absorption at THz frequencies, and an anti-reflective coating in parylene will be added in order to reduce the reflection losses. Moreover, a sapphire substrate will be used in the mixer design and its thickness will be part of the lens extension. An electromagnetic software was used to simulate the silicon lens with the sapphire substrate and the anti-reflective coating. FEKO was chosen because its Ray launching / Geometrical optics solver deals well with dielectrics with big dimensions (Fig.1).

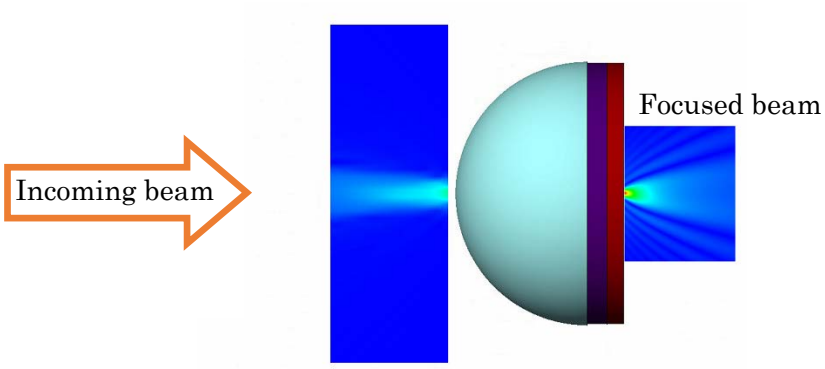

Fig.1: *Simulation of a hyperhemispherical lens in silicon (purple) with a parylene coating (light blue) and a sapphire substrate (dark red), illuminated by an incoming converging beam.*

The beam is focused at the back of the lens, where the SIS mixer circuit will be positioned. I also wrote a Matlab program to calculate the dimensions of the lens, define its position, and to plot the propagation of the beam at the different interfaces (Fig.2). The result is consistent with the electromagnetic simulation.

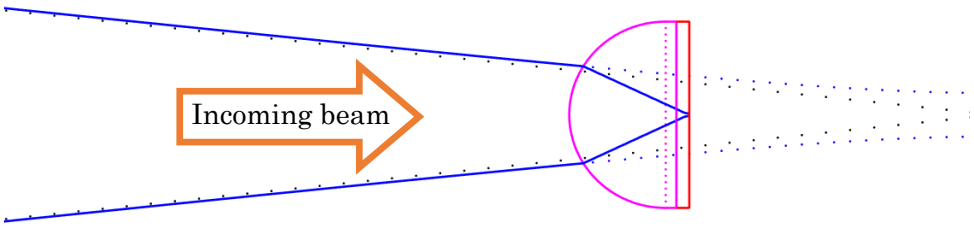

Fig.2: *Propagation of the beam before and inside the hyperhemispherical lens.*

I also designed the double slot antenna of the SIS mixer in order to optimize its coupling with the incident beam focused by the lens. The software HFSS was used to optimize the dimensions of the double slot antenna on the sapphire substrate, in order to obtain a real impedance (imaginary part close to 0). Then, FEKO software was used again to simulate the beam pattern of the double slot antenna with the lens by using the method of moments. This simulation is quite challenging and will be continued at Paris observatory during the following months to obtain better results. After the completion of the optimization process, we would like to present this topic at an academic conference.

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３．この制度について何か御意見がありましたら、お書きください。 (Please provide any comments about this program.)
This program is a good opportunity for other institutes to collaborate with NAOJ. I especially appreciated the very short delay between the application and the acceptance by NAOJ.