FINAL REPORT: NEWFOCUS - Short Visit Grant 3955

Purpose of the visit.

The main aim of the visit was the design of planar antennas based on extraordinary transmission (ET) concepts, with a possible application in quantum cascade lasers (QCL).

The previous knowledge of the Laboratory of Millimeter and Terahertz Waves at the Public University of Navarre, in Pamplona, of ET structures at millimeter waves joined to the vast experience of the Institute of Electronics, Microelectronics and Nanotechnology, in Lille, on QCLs was an optimal background to develop antennas based on ET. In the past, several flat antenna prototypes were designed and measured by the Laboratory of Millimeter and Terahertz Waves at microwave frequencies. In turn, the Institute of Electronics, Microelectronics and Nanotechnology had published novel approaches of antennas for QCL based THz sources such as a horn antenna located at the laser facet. The common effort of both institutions could lead to the design of very interesting antenna prototypes due to the beam-shaping capabilities of the ET based antennas

Description of the work carried out during the visit.

During the visit, the work was mainly concentrated on the discussion and analysis of different approaches to fabricate the antennas. The background of the Laboratory of Millimeter and Terahertz Waves is mainly in the design and measurement of prototypes and not in the fabrication process. The the Institute of Electronics, Microelectronics and Nanotechnology has a long and consolidated experience in fabrication and measurement of terahertz devices, so the personal interaction and discussion between members of both institution was of primary importance during the visit.

In order to have a better approximation to the fabrication constraints, several simulation studies were carried out where the corrugation profile was changed in order to fit the requirements of a typical Silicon etching manufacture. Likewise, sensitivity analyses were done to evaluate the impact of fabrication tolerances on the final prototype performance.

In addition to the work related to antennas, other topics were treated thanks to the close interaction with the personnel at IEMN. For instance, it was explored the possibility to launch a common collaboration in one-dimensional metamaterial structures at terahertz frequencies.

Historically, the Laboratory of Millimeter and Terahertz Waves has been very involved in the design and measurement of Photonic Band-Gap, metamaterial and extraordinary transmissioin structures and collaborated with Dr. Tahsin Akalin during his Ph. D. research. So, collaboration in any of these topics can lead to a fast design of interesting devices at terahertz.

Description of the main results obtained.

As mentioned in the previous section, the work on the antennas was directed towards finding a geometry that satisfies the fabrication constraints. Several parametrical studies were done. First, the sinusoidal profile was tested, as it has a considerable gain, see Fig. 1 (above). After

finding that such profile could show problems in the fabrication, as a continuous profile is not easy to etch, a triangular profile was investigated instead, see Fig. 1 (below).

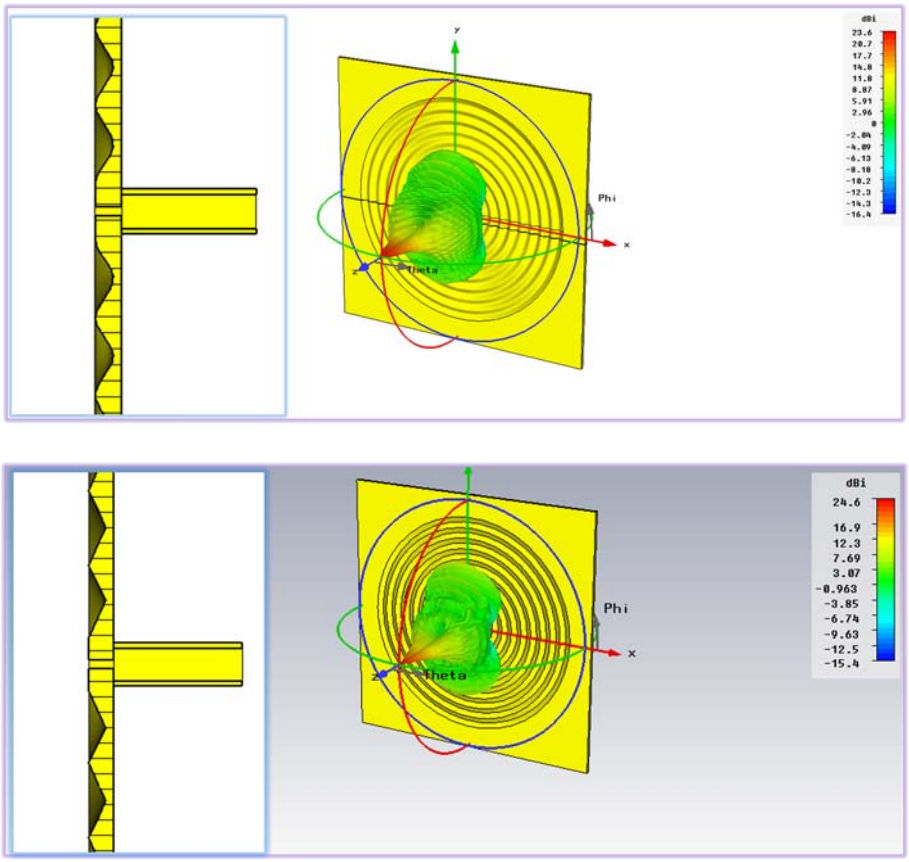

Fig. 1. Antenna prototypes based on ET concepts with annular corrugations (so called "Bull's-Eye" topology). Antenna with corrugations with a sinusoidal shape (top) and triangular shape (bottom). Insets show a detail of the profile in each case.

Remarkably, the simulation showed that the triangular profile has directivity of 24.6 dBi whereas the sinusoidal antenna has 23.6 dBi. Thus, the characteristics of the antenna are improved despite the fabrication constraints. An invited talk on this preliminary idea has been given at the EUCAP 2011 held in Rome.

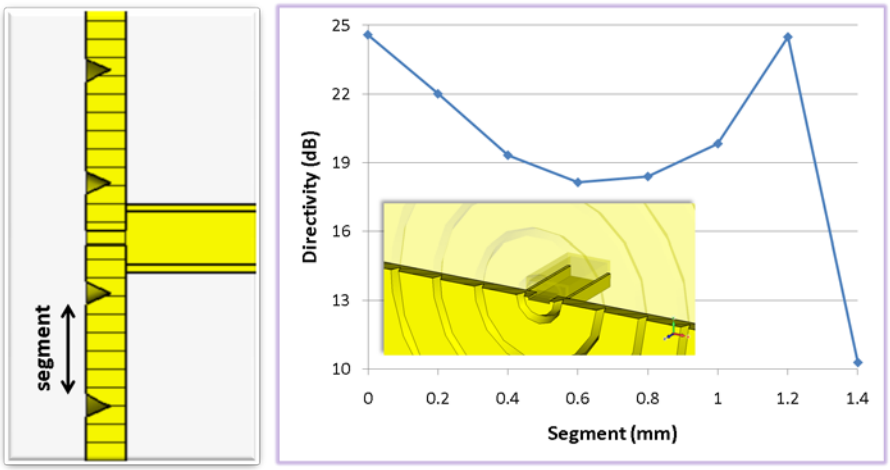

Fig. 2. (left) Detail of the antenna with triangular shape joined with a straight segment. (right) Directivity of the antenna with triangular corrugations as the segment length joining corrugation is varied. Two clear maxima are detected.

Afterwards, a subsequent study was done in order to get an even better approximation to realistic prototypes. It is very likely that in the final result, the triangular profile is not continuous, but rather it has a triangular shape connected by segments, see inset in Fig. 2. Therefore, a simulation study was performed in order to evaluate the degradation of the response in function of the segment length. As it is readily observed in Fig. 2, when the segment is s = 0 mm, the directivity is 24.6 dBi and then it drops as the segment length increases. Nevertheless, around s = 1.2 mm the directivity raises again to 24.7 dBi. So, in principle, the fabrication constraints can be successfully overcome with an appropriate design.

Additionally, there was an initial approach towards a metamaterial microresonator, which was a specific problem under study at the IEMN. The proposed solution is shown in Fig. 3. It consists of a multilayer structure with an input microstrip line on the bottom layer that excites a bi-layer resonant ring through the magnetic field. When the ring is at resonance, power is coupled to an output microstrip line located on the upper layer, see frequency response in Fig. 3 (right).

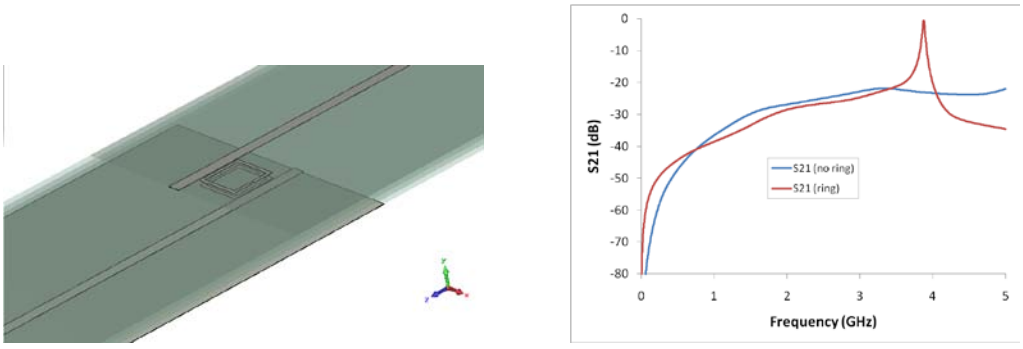

Fig. 3. (left) Multilayer microstrip resonator consisting of two microstrip lines at different levels connected magnetically through a ring resonator. (right) Frequency response with (red) and without (blue) resonator.

Future collaboration with host institution (if applicable)

The activity developed during this short visit is a first contact that should be strengthened as a solid collaboration in the future. There are many common interests between the IEMN and the Laboratory of Millimeter and Terahertz Waves and the relation between both institutions is excellent. Therefore, a longer visit is foreseen in the near future. In particular the applicant will try to apply for a Exchange Visit Grant or to get an Invitation grant to go to the IEMN in July.

The collaboration topics will be again in corrugated antennas and planar technology at terahertz. In this case, a deeper work will be done in order to fabricate and characterize structures.

Projected publications/articles resulting or to result from the grant (ESF must be acknowledged in publications resulting from the grantee's work in relation with the grant).

During the short visit, a contribution to the Infrared, Millimeter Waves and Terahertz Conference (IRMMW-THz 2011) to be held in Houston TX USA was prepared and submitted. The topic of it was on corrugated antennas for quantum cascade lasers and ESF funding was properly acknowledged.

Additionally, during the short visit one of the collaborators at the Laboratory of Millimeter and Terahertz Waves presented some initial results of the topic at the 5th European Conference on Antennas and Propagation, EuCAP 2011, held in Rome, where funding of the ESF was acknowledged as well.

It is also planned the publication of the results in journal papers like IEEE-THz Science and Tehcnology, where it will be duly acknowledged ESF funding.