Abstract:
Various resonant structures combined with lumped and distributed circuit elements were designed for the purpose of identifying an array configuration to efficiently down-convert frequency of incident radiation both at mm-waves at 100 GHz \((\lambda = 3 \text{ mm})\) and in the long wavelength IR spectrum at around 28.3 THz \((\lambda = 10.6 \mu \text{m})\).

This is a first effort for us in fabricating nano-structures, therefore a major part of this effort was aimed at getting acquainted with the tools and methods of nanofabrication. We were looking for answers to questions such as what is realistic and what is not in fabricating thin film circuits with sub 100 nm features? Some other questions were: what are the limits of resolution and limits on circuit complexity today’s e-beam lithography technology can support? Of special interest for us was to develop a feel for what are the limits on reproducibility within small areas of a few hundred microns square, and also step and repeat resolution and reproducibility over long distances (over the surface of a 3” or 4” diameter wafer).

Economy (machine use time) for producing large surfaces was another key concern. Answers to all these (and other) questions were very important in the process of determining whether or not any of concepts and novel ideas we have in optical frequency conversion will be practical and realizable.

The patented technique of using connected dipole arrays with diodes and other nonlinear components requires low loss conductive paths at IR frequencies (Au) and low loss, thin dielectric support membranes.

Three different structures were fabricated in two visits to CNF last year. Linear arrays of half-wave dipoles were fabricated in several different configurations using evaporated gold to be used in tests at \(\lambda = 10.6 \mu \text{m}\). Cold-emission diodes in a thin film strip (Au) configuration were made with various gap dimensions (28 nm and larger). Finally we produced some simple resonant circuits (oval shaped loop antennas) with cold-emission diodes incorporated within.

Subsequent measurement tests of these structures showed the expected resonances, however these resonances were at lower than calculated values. Dielectric const of support materials had stronger effect than prior estimation.

Summary:
Our initial experience at CNF (and with CNF’s very capable staff) answered many (but not all) of our questions (and concerns) in a positive way. We have become convinced that the presently available nanofabrication technology—as we experienced it at CNF—is able to support the submicroscopic requirements of our needs.

Up till now we have been bonding the additional lumped circuit components we need for full functionality into the microscopic photolithographically made circuits manually. It is an extremely time consuming and difficult undertaking.

In view of the planned future efforts of going to higher frequencies, to shorter wavelength and smaller dimensions still, it is unavoidable to move to total integration where all array components, diodes, transistors etc. are fabricated together just as in any modern integrated circuit manufacturing. This of course will encompass the use of MBE technology at nanometer scales.

References:
Development of Resonant Structures at 10 µm Wavelength

CNF Project # 1223-04

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Primary Funding:
Boeing IR&D Funds

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Figure 1: One dim. array of dipoles
- Dipoles lined up along a straight line.
- Length of each dipole = 4.12 µm
- Width of dipole = 170 nm
- Separation between dipoles = 750 nm
- Thickness (Au) = 100 nm

Figure 2: Cold-emission tip
- Gold Strip Width = 170 nm
- Gap width = 48 nm
- Tip Radius of Curvature = 12 nm (approx)
- Thickness (Au) = 100 nm

Figure 3: Simple Resonant Circuit
- Loop major axis = 3.72 µm
- Loop minor axis = 2.15 µm
- Loop conductor width 160 nm
- Gap width at cold emission tip = 48 nm
- Thickness (Au) = 100 nm