# Leaky Lens Pulsed Photo-Conductive THz Emitters

Alessandro Garufo, Paolo Sberna, Giorgio Carluccio, Nuria Llombart, and Andrea Neto
Department of Microelectronics
Delft University of Technology
Delft, The Netherlands
{a.garufo, p.m.sberna, g.carluccio, n.llombartjuan, a.neto}@tudelft.nl

Juan Bueno and Jochem J. A. Baselmans
Netherland Institute of Space Research (SRON)
Utrecht, The Netherlands
{j.bueno, j.baselmans}@sron.nl

Joshua R. Freeman, David R. Bacon, Lianhe Li, Edmund H. Linfield and Alexander G. Davies
School of Electronic and Electrical Engineering, Institute of Microwaves and Photonics
University of Leeds
Leeds, United Kingdom
{j.r.freeman, d.r.bacon, l.h.li, e.h.linfield, g.davies}@leeds.ac.uk

***Abstract*— Laser pumped photo-conductive lens antennas (PCAs) use ultra-short excitation of lasers to generate pulsed radiation in the THz regime. State of the art PCAs suffer from high dispersion and low radiation efficiency over the large generated bandwidth, due to the poor coupling between the antenna and the dielectric lens. In this work a leaky lens PCA is proposed and designed in order to overcome these issues. This structure aims at a 1:15 bandwidth (0.1 THz – 1.5 THz). The electromagnetic analysis and the power budget of the leaky lens PCA are shown and compared to a standard PCA with the same antenna geometry, demonstrating the much higher non-dispersive radiation efficiency of the former device, under the same optical excitation. The manufacturing process of the leaky PCA is also discussed.**

***Keywords*— *Photoconductivity, THz photoconductive antenna, THz radiated power, THz source, Leaky wave antenna, Lens antenna.***

## I. Introduction

Photo-conductive antennas, thanks to the interplay between the applied bias voltage and the laser pumping of the constituent semiconductor material are able to radiate electromagnetic power up to the THz frequencies. Owing to the fact that PCAs are compact devices, they have been extensively employed for the THz time-domain sensing and spectroscopy in different applications (e.g. chemistry, solid state physics and industrial process monitoring) [1]. In the recent years numerous efforts have been made to push the upper limit of the PCA emitted bandwidth and power [2] - [3]. However, the coupling of the antenna with the dielectric lens has still to be properly addressed, hence, the PCAs are suffering from high dispersion and poor radiation efficiency over the large generated bandwidth [4] - [5]. In fact when a planar antenna is located at the interface between air and a dielectric, it mostly illuminates the lateral part of the dielectric lens, resulting in a total poor radiation efficiency. On the other hand, when a small air gap is put between the antenna and the lens, the antenna supports leaky rays with reduced propagation angle, with respect to the antenna plane normal, thus the central part of the lens is mainly illuminated (the radiation efficiency is greatly enhanced [4]).

In this work we propose and describe the design of a membrane-based leaky-lens PCA, demonstrating its non-dispersive behaviour over a large bandwidth, if compared to an equivalent standard antenna. The proposed leaky slot emitter aims at a bandwidth from 0.1 THz to 1.5 THz. A prototype has been manufactured and power and energy spectral density measurement will be presented at the conference.

## II. Leaky Wave PCA

### *A. Leaky-wave PCA design and prototype*

The membrane-based (thickness: 2 μm) leaky PCA consists of a bow-tie (gap sizes 10 μm x 10 μm) patterned in a metal ground plane that is deposited on a low-temperature grown GaAs square membrane (side: 3 mm), which is in turn suspended from a semi-insulating GaAs frame. The Si lens (radius: 5 mm, extension 0.3 times the radius) has been mounted at an electrically small distance from the antenna to efficiently illuminate the lens (see Fig. 1).

### *B. Electromagnetic analysis*

The electromagnetic analysis of the radiation properties of the leaky lens slot and a standard bow-tie PCAs has been carried out by using the Norton equivalent circuit for photoconductive generators, and the electromagnetic model of the Quasi-Optical (QO) channel proposed in [2] – [3]. It has been assumed that both antennas have the same electrical, optical and geometrical parameters for the semiconductor gap. For the pumping laser, it has been considered a Gaussian beam with a carrier frequency of 375 THz, a pulse duration of 100 fs and a repetition rate of 80 MHz. Fig. 2 and Table I show respectively a comparison of the energy spectral density and the radiated power between the leaky slot PCA and the standard PCA. The results clearly show the better performances in terms of matching and radiation efficiency of the leaky slot PCA. Considering a higher value of laser power (80 mW), a better impedance match between the photoconductive generator and the leaky slot antenna is reached. A further advantage of using the leaky lens antenna for pulsed PCA lies in its ultra-wideband non-dispersive behavior and stable phase center [4] – [5], which make such antenna ideal as reflector feed [6] to obtain ultra-wideband high gain QO systems (i.e. THz time-domain systems). The average powers radiated by the antennas ($P_{source}$), have been evaluated by integrating the energy spectral densities over the operative bandwidth. $P_{available}$ is the available power that the sources can generate, if the antennas were matched to the photoconductive source impedance. The average power radiated by the antenna lens ($P_{lens}$) has been evaluated taking into account the front-to-back, dielectric and reflection losses. While the energy spectral densities, radiated by the antenna lens feeds have been computed assuming both PCAs lossless and using the respective impedances.

## III. Conclusions

In this work the design and the performance of a leaky lens PCA emitter has been presented and discussed. This solution helps to significantly enhance the radiation performance and beam quality of PCAs. The proposed structure aims at a 1:15 bandwidth (0.1 THz – 1.5 THz). The dispersion and the power budget of the radiation of the proposed leaky lens PCA has been analysed and compared to a standard PCA. Energy spectral density and power measurements of the first prototypes will be presented during the conference.

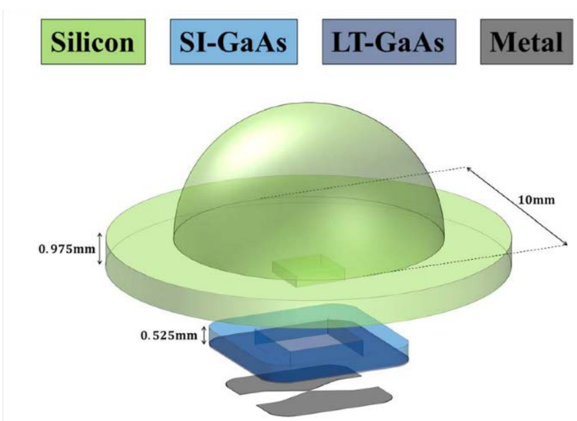


Fig. 1. Designed leaky lens PCA structure.

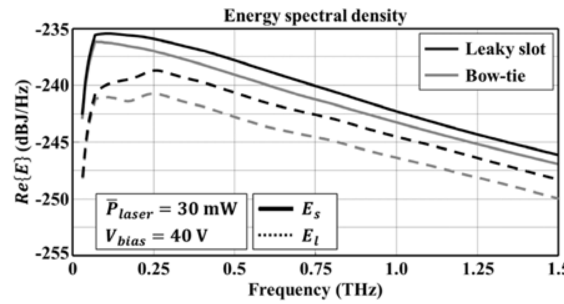


Fig. 2. Simulated energy spectral densities: the solid line represents the density radiated by the antenna $E_s$, the dashed line represents the density radiated by the lens $E_l$.

TABLE I.

| | $P_{available}$ | $P_{source}$ | $P_{lens}$ |
|---|---|---|---|
| Bow-tie ($P_{laser}$ = 30mW) | 355 μW | 229 μW | 94 μW |
| Leaky slot ($P_{laser}$ = 30mW) | 355 μW | 291 μW | 146 μW |
| Leaky slot ($P_{laser}$ = 80 mW) | 946 μW | 924 μW | 462 μW |

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