OPTHER

OPTICALLY DRIVEN TERAHERTZ AMPLIFIERS

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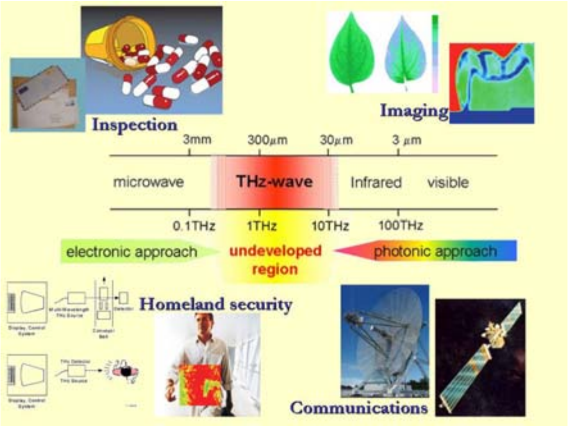
WHY THz AMPLIFIERS?



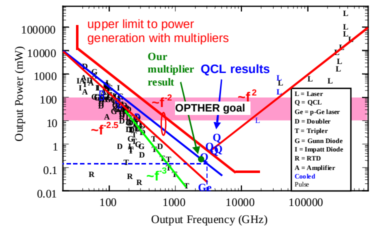
THE THZ REGION AND THE POSSIBLE APPLICATIONS

The potential of Terahertz (THz) in the field of communication, imaging, detection of concealed explosives and chemical or biological agents determines the great interest in applications of this technology to many different fields [1]. Spectral signatures of a large amount of substances of interest are in the THz range (0.1 – 3 THz). Since THz frequency range radiation can be transmitted through concealing dielectric barriers like clothing, packaging, corrugated cardboard and most of the material used in normal clothing permit the real time detection of potentially dangerous materials. In particular, a THz image can be spectroscopically analyzed to recognize the concealed content. Further, THz radiation has a photon energy a million times less than that of X-rays and produces no biological tissue damage, apart the generalized thermal effects.

Finally, security systems based on THz radiation can be utilized for large crowded areas as train/subway station, market, buildings halls, airport for detecting any weapon, explosive or dangerous substance, without any harm to people and animals.

In this context, there are three different well established approaches to the THz generation: optical downconversion (such as photomixing), direct generation of THz radiation using lasers such as QCLs and traditional vacuum tubes such as backward-wave oscillators (BWO). However, the BWO is too bulky and difficult to operate and therefore less useful in this context.

A possible solution to this problem is represented by the realization of a THz amplifier that can boost the performances of the already existing THz sources.



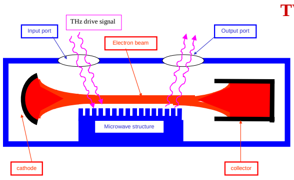
SOURCES IN SUBMILLIMETER WAVE RANGE

THE OPTHER PROJECT

The project OPTHER (Optically Driven Terahertz Amplifiers), is a STREP project proposal for ICT-2007.3.5 Photonic components and subsystems that has been founded for a total 4,100,285 euros of by the EC under the Seventh Framework Program.

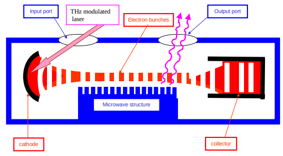
The OPTHER project aims at solving the power/size problem of THz systems by a radical new approach. Rather then looking for a miniaturized THz source providing the required power, we plan to use available optical sources (such as Quantum Cascade Lasers or photomixing systems) and boost their performances by the integration with a compact, efficient and reliable novel vacuum THz amplifier that will be projected and realized on purpose. To achieve such goal we will make use of some significant recent breakthroughs in the field of nanotechnology and optical components. The novel THz amplifier will be based on field emitting carbon nanotubes (CNT) used as cold cathodes combined together with slow wave structures realized thanks to LIGA and DREI technologies for micro-fabrication.

TWO DIFFERENT APPROACHES



THz drive signal amplifier

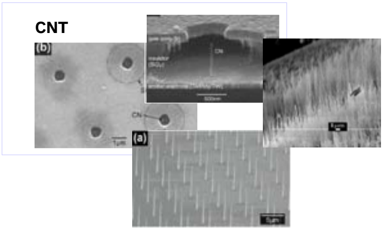
The THz drive signal amplifier , is similar to the conventional klystron and travelling wave tubes (TWT). The electron beam is emitted from the cathode, accelerated by the voltage between the cathode and the anode , focused by the magnetic field in order to go through the interaction structure. An electric field in the interaction structure causes density and velocity modulation , which results in bunching of the beam; in the output section bunches are strongly decelerated by the electric field , and give energy to the wave . There are an input port for the injection of the drive signal which modulates the beam , and an output port for the extraction of the amplified signal . The THz drive signal is generated for instance by a Quantum cascade laser (QCL) or by laser photomixing on an antenna coupled photomixer . The main advantage of this approach is its full compatibility with any already existing THz source, which in general suffer from too limited output power for really practical applications.



Optically modulated beam THz amplifier

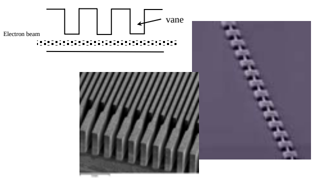
The Optically modulated beam THZ amplifier is similar to the conventional inductive output tube (IOT). In this case, emission of electrons by the cathode is controlled by the microwave drive signal (like triodes) and accelerated electron bunches (instead of a continuous flow) interacting with the slow-wave structure give rise to the output THz wave. As a pre-modulated electron beam triggers the amplification process, much shorter slow wave structures (SWS) can be used (In TWTs the helix length can be reduced by a factor of 3). Due to the SWS length reduction, losses are reduced and the collimating optics are easier to fabricate. As a conclusion, with this second scheme, as high interaction yields are anticipated, delivery of high power output should be facilitated. This second solution, is much more innovative and challenging

THE COLD CATHODE



We will focus on the realization, characterization, and optimization of the cold cathode emitting source based on Carbon Nanotubes (CNTs). Such kind of cathodes offer significant advantages for THz frequency amplification respect to thermionic cathode since they can work at room temperature, thus avoiding the warm up times, they are mechanically extremely strong and have good chemical stability.

INTERACTION STRUCTURE



High electrical conductivity material is needed for the THz structure in order to avoid excessive losses. High conductivity copper will be provided. The technological processes available for this purpose are LIGA and SU-8-based DRIE.

KEY ISSUES OF THE PROJECT

We identified the following activities as the key issues towards the development of the proposed integrated system:

- Definition, design and realization of a THz source with a performance suitable for THz remote sensing applications (such as dangerous substance detection or concealed weapons imagery).
- Identification of an optimal e-beam/THz coupling for the amplification process
- Identification of an optimal structures for coupling THz signals to the amplifier, for both input (when THz originates from QCLs or laser mixing) and output (waveguide vs. free space)
- Realization of an optimized Cold Cathode based on Carbon Nanotube (CNT) with an adequate field emission current
- Definition of a fabrication procedure based on a state of the art technological process (DRIE, SU-8.) for repeatable manufacture of a THz nanostructure amplifier.
- Definition of a measurement setup/procedure for the accurate characterization of THz amplifiers.

PROJECT GOALS

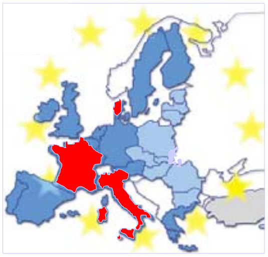
The design and realization of the two solutions of THz source are constrained from the following target:

- Working frequency 0.3-2 THz
- Output power 10-100 mW
- Gain 10-20dB
- Bandwidth > 1%
- Room temperature or moderate cryogenic cooling (100-200 K)
- Compact amplifier : of the order of 1 dm^3
- Lightweight: <1kg

These targets will also produce the following characteristics of the device

- Wide frequency band option
- Reliable (lifetime < 10^4 h)
- Low cost (< 20000 euro)

THE CONSORTIUM



The consortium OPTHER involves the University of Rome "Tor Vergata", that is the project coordinator, the Technical University of Denmark, the National Center for Scientific Research (CNRS) in Paris, and three industrial partners: the SELEX Integrated Systems, Thales Research Technologies and Thales Electron Devices Ltd. France, that are world leaders in systems and components production for high frequency applications.

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