

University of Arkansas Microelectronics-Photonics Graduate Program

PhD Candidacy Exam – Environmental Topic – March 16, 2011

PROBLEM TO BE SOLVED

One of the fourteen Grand Challenges identified by the National Academy of Engineering is to “Engineer the tools of scientific discovery”. Reaching new milestones in detection, processing, and transmission of energy at frequencies outside commonly exploited spectral ranges requires advances in micro- and nano- technologies (e.g. materials, processes, devices, and/or systems) to improve efficiency, economics, and applications related to analyzing, capturing, converting, storing, or processing energy at these new frequencies.

Your CEO is interested in harnessing recent advances in materials, processes, devices, and/or systems to develop one innovative, cost-effective, specific technology in a single area of your choice related to emission, detection, or application of terahertz radiation. Technologies that employ terahertz (THz; $0.3\text{-}3 \times 10^{12}$ Hz; 0.1-1 mm) radiation have potential in military, security, communications, medical diagnosis, coherent imaging, material analysis, environmental protection, and space science. Materials such as plastic, cardboard, cloth and millimeters of tissue are transparent to THz radiation, which is reflected by metals, explosives and water.

Examples of technologies to develop could include coherent THz emitters or detectors that incorporate superconductor, semiconductor, or nanoscale materials to provide portability, operability at ambient conditions, or other improved performance specifications. For example, electromagnetic materials or metamaterials that are susceptible to an external voltage could provide tunable coupling to THz waves in order to decrease power consumption during THz emission, or improve detection in astronomical, environmental, or biochemical applications.

Examples of areas to exploit could be: New technologies incorporating THz-related materials, processes, devices, and/or systems could improve solar PV efficiency by exploiting the capability of THz waves to detect free carrier concentration and mobilities in photo-excited semiconductors. Low photon energies and sensitivity of THz to far-infrared wavelengths could provide new opportunities for novel THz imaging processes, devices, or systems to image moisture levels in ecological samples or foods; distinguish epithelial cancers or tumor margins; reveal important substrata beneath coats of plaster or paint in centuries-old artwork; or provide quality control or process monitoring during manufacture of packaged goods, like inspection of dielectric insulators or polymers.

Your task is to apply your background in nano to micro materials, devices and processing to develop *one* cost-competitive, practical, innovative THz technology to apply to *one* of the above (or closely related) areas. Your solution should consider material, process, device, and system aspects of the technology and product.

YOUR DELIVERABLE

Your task is to write an internal proposal for your corporate officers describing your approach to this issue. The proposal should include the following:

- Executive summary (one page)
- Risk assessment roadmap form (one page)
- Full proposal (15 pages maximum)
- Appendix A: Bibliography (no page limit)
- Appendix B: Ranked list of intellectual property documents examined (no page limit)

At a minimum, be sure you address all of the following:

Current Science and Technologies - What is already being done in this area by other researchers, companies and governmental institutions? Describe the current state-of-the-art for both the science and the implementation. Use diverse resources such as science literature, journals, conference proceedings, the internet, patents or other sources of existing public knowledge. **Cite all references you use and quote any word-for-word transfer to your report.**

Your Design Approach – What is the basis for your design approach to the problem? Why is your product better than existing products? What product attribute(s) allow market penetration to achieve profitability? Address scientific *and* engineering aspects of these questions.

Testing and Qualification - Describe a set of tests you will use to demonstrate that your approach is effective and that your implementation of the solution will launch successfully.

Cost Analysis – Identify cost and market issues that will impact the pricing strategy of the solution you have proposed. Consider such things as: the major cost items that would impact the implementation; which elements of your implementation solution would be handled in-house versus externally-sourced; major risk elements that could drive up costs if the primary path item fails; costs of IP licensing needed, etc. Provide justification and/or reasoning behind your decisions. Estimate manufacturing cost for the total system as the product reaches mature product stage, so the marketing team can determine potential market size. Avoid subcontracting manufacture or assembly of any proprietary component outside the company, because the CEO is concerned with potential IP leakage.

Intellectual Property – In Appendix B, list in rank order of importance ***all*** commercial, academic, and governmental IP sources that were consulted while formulating the answer, including reference data. For instance, include the patent number; title; inventor name; and assignee name for a patent. Discuss the 3 most significant competitive approaches to your solution in the 15-page document. Compare strengths and weaknesses of these approaches relative to your own. Recommend how these IP threats should be handled.

Most importantly - this is just a minimum list of issues you might consider. There may be many more. The point is that your report ***should contain the evidence*** needed to make an effective and compelling case to your CEO in order to insure that she makes the right decision.

Hint – Clearly state your hypothesized solution. Identify its innovation(s) and advantages relative to state of the art. Describe both existing data, and work needed to support each aspect of the hypothetical solution. Consider theoretical, fabrication, and characterization aspects: for each, identify software/equipment and methods to use, parameters to vary, anticipated outcomes, and possible alternatives in the event of unsatisfactory results. Discuss material, process, device, and systems aspects of your solution. *Refine* your hypothesized solution as you accumulate information and prepare the manuscript. **Remember:** clearly distinguish what is known from what is hypothesized or not known. What is needed to distinguish the important things to know?