

**University of Arkansas Microelectronics-Photonics Graduate Program
PhD Candidacy Exam – March 2007**

**Advanced Devices in Photonics at the Micro to Nanoscale
(including associated materials and processing)**

PROBLEM TO BE SOLVED

You are CTO of Gaseous Analytical Specialists (GAS), a company that specializes in photonic devices. In particular, GAS is a leader in the R & D of quantum cascade lasers, and you see great potential in these systems for applications in trace gas analysis. These applications might include atmospheric monitoring, workplace surveillance, and breath analysis for health applications, among others. More specifically, trace-gas sensing and analysis in applications such as surveillance and plume tracing within the atmosphere above urban and industrial areas requires the ability to detect tiny fluctuations in gas concentrations. Thus, GAS's overall goal is to develop photonic devices and methods that can detect minute perturbations in the chemical composition of gases, particularly those containing carbon compounds. Since the vibrational/rotational spectra of most organic compounds have distinct features in the mid-IR range (wavelengths of 2- to 20- μm), the detection schemes will need to focus on this range.

Your job is to study and design methods for detection of trace organic gases based on quantum cascade lasers, and to make recommendations for the best overall system approach. This study should provide a survey of competing technologies for laser-based trace-gas sensing, pointing out advantages and disadvantages of each. A clear explanation of quantum cascade lasers and how they work should be given, as well as the advantages they offer for the specific application under study. Improvements to quantum cascade lasers that may warrant further R & D for applications to trace-gas sensing should also be discussed.

The specific requirements that must be met in order to reach your system goal include:

- Capable of achieving almost any mid-IR wavelength without changing the material system.
- Capable of molecular selectivity for multiple gas analysis. Single gas analysis per sampling period is the minimum acceptable configuration, with multiple gas analysis from a single sample seen as a first-order marketing advantage.
- Capable of detection of trace gases at the level of a five parts per billion, with the five-year detection goal of ten parts per trillion.
- Capable of continuous operation with a sampling frequency of once per minute.
- Maximum sample volume allowed per analysis is ten milliliters.
- System dimensions must be less than three feet (length plus width plus height), with smaller size identified as a second-order marketing advantage.
- An external power system may be assumed, with mission appropriate independent internal power identified as a second-order marketing advantage.
- Mission appropriate system data capture and transfer requirements should be discussed, but usage of off-the-shelf components for any additional functionality beyond trace gas analysis is encouraged.

YOUR DELIVERABLE

Your task is to write an internal 15-page combined technology implementation and product realization plan for GAS's corporate officers describing your approach to the issues introduced above. In addition, be sure you also address at least all of the following:

Current Technologies - What is already being done in this area by other researchers, companies and governmental institutions? The current state-of-the-art for both the science and the implementation should be described, making use of diverse resources such as science literature, journals, conference proceedings, the internet, patents or other sources of existing public knowledge. Be sure to cite all references used.

Your design for Manufacturing – Device specifications have already been listed, as has the limitation that requires a quantum cascade laser based solution.

Manufacturing Flow - Detail the step-by-step procedure for producing the quantum cascade laser sensor within the device, as well as general information on the system manufacturing. Because the CEO is concerned with potential IP leakage if the device is built outside of the company, no subcontracting of the manufacturing or assembly of any proprietary component, or of the final device, outside of the company will be allowed.

Testing and Qualification - Describe a set of tests and demonstrations that you will use to demonstrate the effectiveness of your approach and to give confidence that the implementation of the solution will launch successfully. GAS cannot afford to lose market share, and needs to ensure that the all new product launches go smoothly.

Cost Analysis – Describe the elements of the cost analysis that would be performed before a final implementation decision could be made. You should include 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 components, etc. Be sure to include not just the “what”, but also the justification and/or reasoning behind your decisions.

Intellectual Property - In an appendix to this exam, list in rank order of importance all IP sources that were consulted while formulating the answer, including the full list of examined documents along with key important reference data. For instance, if the IP source is a patent, include the patent number; title; inventor name; and assignee name. (The full list will not be counted as part of the 15-page limit.)

Within the 15 page document you must fully discuss the three that are the most significant IP threats to your solution, making comparisons of strengths and weaknesses of these approaches relative to your own. Address your recommendations on how these IP threats should be handled.

Of course this is just a minimum list of issues you should 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.