MicroPhotonics systems: *life beyond microelectronics*

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1. INTRODUCTION

In 1959, the physicist Ricahrd Feynman advised his colleagues that "there's plenty of room at the bottom". He envisioned a discipline devoted to manipulating smaller and smaller units of matter. "I am not afraid", he wrote, "to consider the final question as to whether, ultimately – in the great future - we can arrange the atoms the way we want, the way very atoms, all the way down". However, in early 1980's the doom and gloom of silicon MOS transistors was foreshadowed and scaling of the humble MOS transistors beyond 140nm appeared as the impossible dream.

Manipulation of material science, the emergence of low-K material and copper technology together with new techniques in lithography and processing have paved the way for revised predication that has foreshadowed the feature sizes in the order of 20nm – 30nm will occur somewhere between 2012 and 2016.

Coupled with these developments, nanochemists have began to probe into matter and now Nanochemistry is beginning to shape the future of new materials and better understand the unique properties of assemblies of atoms and molecules on a scale that range between that of individual building blocks and the bulk material, thus confirming Feynman's vision. At this level quantum effects can be significant and innovative ways of carrying out chemical reactions become possible.

1.1 newICT Domain

Lightwave technology (Photonics) synonymous with high speed networks is beginning to show its imprint in areas that not so long ago appeared to be far removed from the conventional ICT (Information Communication Technology) arena. Photonics is an alternate to electronic systems to transmit, distribute, and process high volumes of digital information at 'lightening' speed. However, other than its communication properties, light's interface with other materials makes it an ideal precision measurement, fine process, and diagnostic tool. Integration of microelectronics and photonics with nanochemistry – *new*ICT - becomes the new frontier of research that spans from health sciences and health care, environmental management, smart energy management through to new innovations in man-machine interfaces, processing and communications.

Example of integration of microelectronics and light-wave technology with applications in the environmental domain is illustrated in Figure 1. A nano-sensor is organised to respond to a specific gas and specific wavelengths. Through wireless communication, data is managed and real-time responses activated.

Different gases create different colouring reactions with colouring compounds inside the nano-plate. When a certain gas adheres to the plate, the colouring compounds change colour. Colour changes can be easily measured by combining a sensor with a small Vertical Cavity Surface Emitting Laser (VCSEL array and a photodetector array. By measuring the photocurrents of light within a certain time period, it is possible to determine the different gas concentrations over a given time span.

For example, a *nanophotonic* clinic can be created using multifunctional nanoparticles in which therapeutic or monitoring agents are encapsulated or located on the surface, and activated or monitored with light waves. Nanoparticles would seek out targets such as cancer in the human body, would identify its location through fluorescence activation for example. They would allow an encapsulated drug to be photo activated locally thus initiating treatment. Subsequently the process can be monitored for required delivery rate. Molecular biology alone is unable to respond to requirements of imaging cells and their constituents such as DNA creating new challenges for the light-wave technology. The ability to probe these basic mechanisms through integration of nonlinear optical microscopy and microelectronics as the source of stimuli and optical imaging to monitor the results provides new opportunities in medical diagnostics and treatment.

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Embedded biophotonic sensors for example that could be powered and monitored remotely to observe a wide range of physiological conditions such as pulse rate, blood sugar, blood oxygen, blood pressure, status of internal tissues etc., would provide important enabling capabilities for robotic microsurgery. The notion of intelligent biopsy and surgery providing health professionals with instant feedback during surgical procedures is an important challenge.

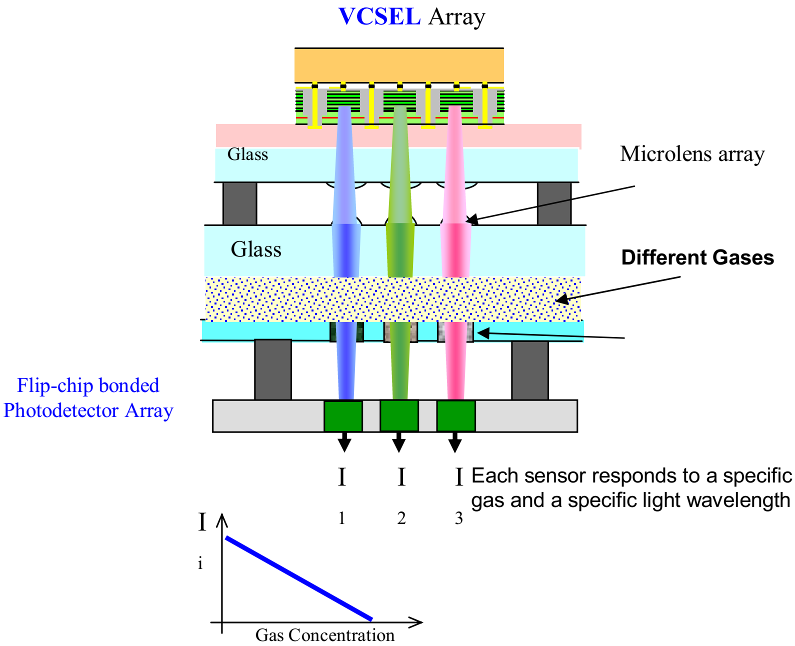

Figure 1. Environmental nano-sensor that responds to specific gas and wavelengths.

2. MICROPHOTONICS AND BIOPHOTONICS INTEGRATION

The revolutionary marriage of microelectronics and photon based sciences with that of nanochemistry will enable the development of novel circuits and systems with extraordinary new properties relevant to nearly every sector of the economy. This integration supported by Bio- based environment provides the foundation for a future in which information processing, sensing, imaging and communication systems.

New generations of auto-sensor health monitoring devices based on intelligent diagnostics such as intelligent pacemakers that respond to the individual's activity needs, wearable sensors and communicators etc. become part of an important "tool-kit" to serve our ageing population. The wide array of outcomes that flow from the dynamic integration of microphotonics, biophotonics, nanochemistry, is shown in Figure 2.

MicroPhotonics will bring together the impacts of the **newICT** with applications to Health, the Environment and Energy. Innovative devices for the newICT industry, include highly integrated electronic devices and interconnection technology for logic chips and system-on-chip integration wireless capacity, logic circuits with ultra-high integration density and minimum leakage power, highly integrated sensor sub-systems driven by high-performance nanoelectronic actuators, nanoscale devices, such as single electron transistors, quantum wire transistors, nanowires, nanotubes, and bistable molecular switches, magnetoelectronic technologies, microelectronic devices based on new materials, such as polymers and amorphous, polycrystalline or microcrystalline silicon-based composites, actuators and interfaces between optical and electronic signal processing. Nanoscale sensing technologies with scales and accuracy beyond currently accepted limits, and near zero power consumption and reduced emissions, will greatly improve safety and create new scopes for shaping our society.

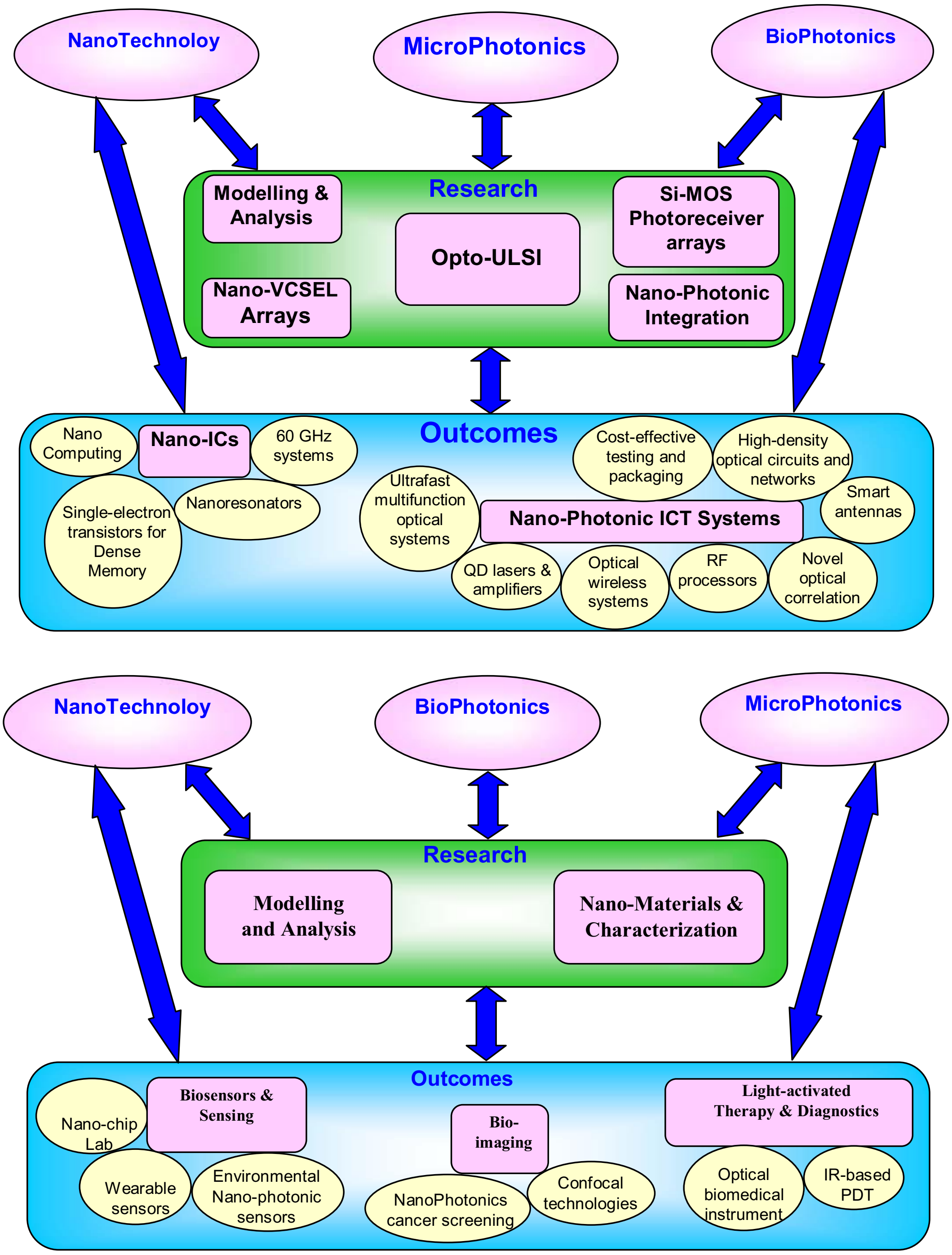

Figure 2. Array of outcomes that flow from integration of microphotonics, biophotonics, nanochemistry.

3. INTEGRATED MULTIFUNCTION PRODUCTS

Environmental sensors in the home will lead to smart home management with energy and water savings. The same enabling technologies will benefit agricultural management systems and smart antennas with improved communications will deliver these solutions more widely than ever before.

Sensing technologies will enter new realms of sensitivity and size, with associated reductions in cost. Sustainability will be a more easily achieved objective for our natural resources and the environment. The resulting new technologies interact easily and are interdependent in their applications is illustrated in Figure 3.

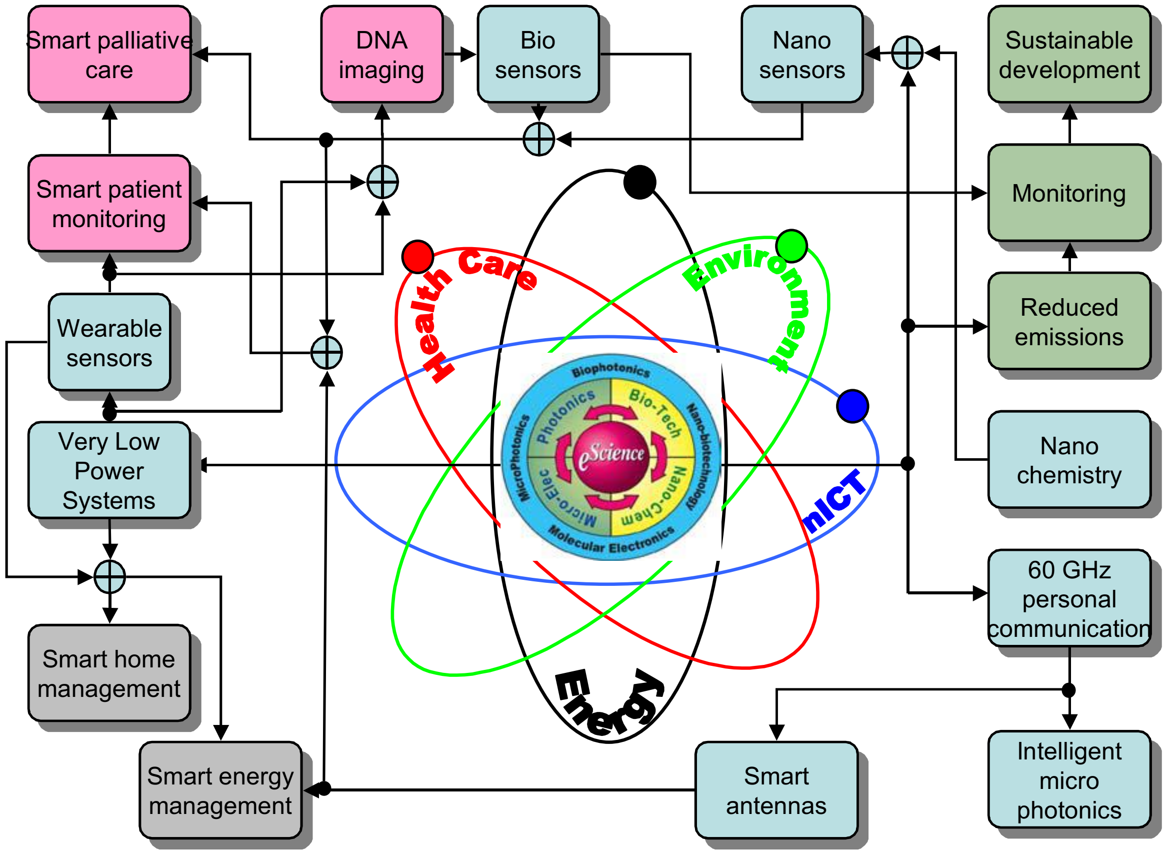

Figure 3 Adding technologies to create outcomes

4. OUTLOOK

The predicted world market for *optical communications components* will be more than US$24 billion by 2006 and more than US$70 billion dollars by 2011. Within this platform *MicroPhotonics* will play a key role in providing intelligence for all types of components. *new*ITC based products, with projected total worldwide market size of over $1 trillion is conjectured to create new opportunities in efficient manufacturing process through nanoscience and nanoengineering through to intelligent environmental management and improve the quality and extend human physical capabilities.

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