

Towards a foundry model for micro- and nanophotonic ICs

A vision for Europe

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Introduction: impediments for a breakthrough of micro- and nanophotonics.

Photonics is a rapidly growing sector in the global economy. Optical communications, optical disks, digital cameras, lighting, lasers and optical sensors are just a few examples. In comparison to electronics, most photonic equipment is still large and expensive. Just like in micro-electronics, many applications can be realized in a much more compact and cost-effective way by integrating the required functionality in a single chip.

So far, the progress in photonic integration technology has been hampered by the large variety in photonic devices and technologies, and the fact that most integration technologies are specific for the applications for which they have been developed. As a result the market for integrated photonics is too fragmented to justify the investments for developing an integration technology to a level that really leads to substantial cost reductions, and this, in turn, prevents rapid growth of the applications.

Vision: towards a generic integration technology

The way to break out of this deadlock is by developing a small number of generic integration technologies with a level of functionality that can address a broad range of applications. Such technologies, which should be made accessible via foundries, can address markets that are sufficiently large to pay back the development costs.

This is quite similar to what happened in microelectronics. The success story of microelectronics can be repeated in photonics if we succeed in developing a generic integration technology that supports integration of a set of elementary components: passive waveguide devices like couplers and filters, optical amplifiers (for use in lasers and other devices), modulators and detectors. By combining designs of a number of users for a single batch of wafers the cost-advantage can also be achieved for smaller volumes. This is similar to the model that is offered in micro-electronics by Europractice (www.europractice.com).

A first step into this direction has been taken by a number of so-called custom foundries that have opened their fab for developing components tailored to customer needs. They make it possible for customers to develop chips for custom applications without the need to own a fab by themselves (fabless operation). In this way the costs of the fab and common parts of the process development can be spread over several customers. The entry costs remain relatively high, however, because these foundries do not have a well developed open design interface and because usually additional process development is needed to tailor the process to specific customer demands.

The next step is, therefore, concentrating the existing know-how in development of a few generic integration technologies that can address a broad range of applications. These generic technologies should be made available by a small number of foundries that address sufficiently large markets to realize the scale advantages that will lead to substantial cost reductions. The development of

generic technologies should be accompanied by development of a well-defined design interface, and by stimulating design houses to form the bridge between these foundries and users that are not familiar with the technology. We will call this development the generic foundry model, and foundries that provide open access to generic technologies “generic foundries”, to distinguish them from today’s custom foundries. For achieving a broad penetration of photonic ICs in fields like telecommunications, health care, sensors and metrology, it is of utmost importance that they come into existence on a short term.

The complexity of processes that support integration of a number of elementary components, the need for development of a proper design interface and the extreme demands on yield and performance, make the development costs of a generic foundry prohibitive even for the larger companies.

Development of a generic foundry should, therefore, preferably be done by one or a few consortia consisting of chip manufacturers and custom foundries, photonic CAD-tool developers, equipment manufacturers, research institutes and a group of strongly involved users. Government funding will be essential to stimulate such a cooperation, which will get a large impact on the European economy, if it is successful. This is similar to the way in which the developments in micro-electronics have been stimulated in the eighties and nineties of the last century.

Industrial perspectives

Up till the beginning of this century the main drive for photonic integration came from the optical communications market. Large investments in technology and equipment development have brought the first applications of this fascinating technology to the stage of maturity, with many others to follow in the coming years. The WDM transceiver chip set of Infinera is a good example. The rapid development of 10 and 100 Gb Ethernet and the breakthrough of Fiber-to-the-Home in an increasing number of countries offer great opportunities for application of photonic integration technology. Low-cost is a major issue in this field, so integration is mandatory in order to be able to gear up performance and complexity without increase of cost.

The increased functionality and the reduced costs of micro and nanophotonic chips realized in a generic foundry process offers advantages and new possibilities in a much wider range of applications, such as health care, sensors, metrology and consumer applications. Many of the companies in these markets are SMEs, much more so than in telecommunications where the field is dominated by large companies. For these smaller companies development of micro-photonic solutions is completely beyond their own reach and the accessibility of a generic platform technology, in combination with training and design support, is essential for massive penetration of micro-and nanophotonics in these fields.

Inventories made in several European countries have revealed a substantial interest from small and medium enterprises in applications of cheap or medium-priced micro- and nanophotonic solutions, because of the cost reductions, but also because of the novel functionalities that they offer. In many EU-countries it appears to be easy to identify tens of SMEs with an interest in micro-photonic solutions, with a total predicted market volume in excess of 100 M€ per year. We are confident that much larger numbers of companies will get interested once the number of successful applications increases.

Another interesting side effect of the availability of mature integration technology platforms is that also companies and universities in regions and countries with a less developed technological

infrastructure can participate in the research and development opportunities offered by photonic integration.

Research perspectives

The availability of a foundry process with a steadily increasing complexity will create a new field of research for design of components and circuits with an ever increasing complexity, that will pave the way for photonic functionalities that we only can dream of today. But it will also create an increasing demand and increased resources for research on materials and technology, that are necessary to support the challenge of steadily developing new technology generations with improved functionality, which is the driving force behind Moore's law. And finally, it will create a need for research on photonic design methodologies and development of advanced design tools.

The steady technological innovation that is necessary to provide ever more functionality at an essentially constant price, a development that we witness in electronics already for several decades, can only be sustained if research, development and manufacturing go hand in hand.

Required actions: How to get there?

With some exaggeration we may sketch the present situation in Photonic Integration as follows: we have a powerful army that has a great potential in beating the high costs of integration technology, and we have already won some minor battles in the application fields, but the army is still fragmented and struggling for the survival of its own cost reduction solutions. This is not the way in which you win a war. What is needed is consensus about a strategic roadmap.

The FP6 Network of Excellence ePIXnet (2004-2008) is proving to be a successful framework for restructuring the large research community working on photonic integrated chips, including the main industrial players in the field. As a result of the ePIXnet approach, this community is now moving towards foundry-like cost sharing mechanisms, thereby underpinning the increasing problem of affordability of the complex technological infrastructure needed for photonic ICs both in research and manufacturing, in particular at the level of the chip fabrication itself but also in relation to packaging, to advanced nanostructuring and to advanced measurement and simulation techniques.

ePIXnet has created six platforms for advanced infrastructure offering services to the ePIXnet research community, including universities, research institutes and companies. Two of those platforms, the silicon photonics platform and the InP-platform JePPIX, have reached a level of maturity where they feel confident to become independent organisations offering services not only to the ePIXnet community but to any European party and beyond. Already now requests for chip fabrication are being obtained from non-ePIXnet parties both in and outside Europe and both from the academic world and from industrial companies (mostly fabless start-ups). Till August 2008 these two platforms will operate as ePIXnet platforms and thereafter they will become independent, possibly under a joint umbrella organisation.

The ePIXnet initiative offers an excellent starting point for organizing European research in the field of Photonic Integration in a coherent and joint effort. In order to get the required impact to provide Europe with a lead in this field the initiative should be broadened - beyond the scope and duration of ePIXnet - to involve all European key-players in the field, and it should be provided with adequate means to focus existing R&D efforts on a national and a European scale towards a common European approach. This approach will not only be relevant for InP and silicon photonic ICs but also for other technologies (e.g. for applications in the visible).

Photonics21 is the preferred platform for turning the ePIXnet initiative into a strategic pan-European action. To implement this we propose to appoint a task force, consisting of representatives from EPIC, ePIXnet and Photonics21, that will adopt and promote a coherent vision on photonic integration. This vision should focus the R&D effort of the European micro and nanophotonics community, including chip manufacturers, equipment manufacturers and photonic CAD software companies. But it should also provide guidance to the user community, both large companies and SMEs, national and European policymakers and funding organizations. In this way available resources, both in industrial and government organizations can be directed towards a focused effort that will provide Europe with a lead in this field.

This task force will have the following tasks:

1. To integrate the vision formulated in this document in the next version of the Strategic Research Agenda (SRA).
2. To broaden the ePIXnet platform initiatives by involving the relevant and interested European stakeholders, that are not yet on board.
3. To act as a catalyser for initiatives under FP7 (CSAs, IPs, STREPs) which support a foundry-oriented approach in photonics.
4. To make a recommendation to national and European governments and funding agencies to contribute to the development of Europe as a leader in Photonic Integration by defining R&D programs with open calls for projects that make use of and/or contribute to the development of the foundry model. This can be done either by having separate national or European programs or by bringing a number of national programs under a European umbrella, (e.g. ERA-NET). In this way substantial budgets can be directed towards common goals. This approach will lead to substantial multiplicative effects. It can be promoted, for example, by national mirror groups.

Conclusion

A foundry model is of strategic importance for the development of micro- and nanophotonic integration. Europe is in a good position to take a lead in developing versatile generic integration technologies with a broad range of applications. There is a vast reservoir of knowledge and equipment in Europe, but there is an insufficient level of technological convergence. The investments for developing such a technology and the applications that will provide it with an adequate market, are very large, however, and therefore it is essential to develop a concerted action.

Photonics21 is the platform par excellence to organize the cooperation that is needed for Europe to become a leader in this field.