HORIZON 2020

Thermally Integrated Smart Photonics Systems

Sprawozdania

Informacje na temat projektu

TIPS

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Strona internetowa projektu

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Podsumowanie kontekstu i ogólnych celów projektu

The objective of this project is to develop and demonstrate a scalable, thermally-enabled 3D integrated optoelectronic platform that can meet the explosion in data traffic growth within ICT. The Thermally Integrated Smart Photonics Systems (TIPS) program will heterogeneously integrate micro-thermoelectric coolers (µTEC) and micro-fluidics (µFluidics) with optoelectronic devices in order to precisely control device temperature and thus device wavelength compared to commercially available discrete technology. Data traffic is projected to increase sharply (40-80× by 2020) and this is driving an increase in network complexity and the requirement for scalable optoelectronic integration. A major bottleneck to this large scale integration is thermal management. Active photonic devices generate extremely high heat flux levels (~1 kW/cm2) that must be efficiently removed to maintain performance and reliability; furthermore, active photonic devices must be controlled at temperature precision better than ±0.1 °C. Today's thermal technology is at the limit and cannot scale with growth in the network. As a comparison, electronics produce lower heat flux levels (~100 W/cm2) and have a less restrictive temperature requirement of ≤ 85±2 °C.Integration of thermal management onto optoelectronic devices has not been addressed to date and therefore presents a significant knowledge gap that must be filled to enable impact and ensure the EU is at the forefront of optoelectronic technology. While the end goal is driven by telecom/ datacom industrial requirements there are many scientific knowledge gaps that will be filled by the TIPS consortium including inter/intra-chip communications as well as other applications like sensors that seek to leverage silicon photonics platforms.

Prace wykonane od początku projektu do końca okresu sprawozdawczego oraz najważniejsze dotychczasowe rezultaty

The TIPS project is an ambitious endeavour to address the thermal challenges arising from the continuing integration of optoelectronic systems. In particular, we aimed to address the drastically different operating temperatures between active photonic devices and electronics. The computation and modelling for thermal management of the existing devices on a silicon photonics platform was performed to obtain a baseline set of requirements for subsequent design efforts to incorporate µTEC and µFluidics. The simulation results indicated that our device-integrated µTEC design can achieve refrigeration levels necessary for cooling a range of hybrid active photonic devices to ensure performance suitable for high spectral efficiency communication applications in high ambient temperature environments, e.g. > 55 °C. The analysis pointed out the energy benefit of targeted spot cooling in an integrated optoelectronic system and is encouraging from the point of view of implementing aggressive optoelectronic integration strategies required to deliver the next generation of high bandwidth communication systems.

Based on the simulation results, thermoelectric materials based on BiTe alloys were developed. Micro-thermoelectric coolers were fabricated showing cooling of 10 °C for self-standing coolers, while the integrated coolers on the device emulating photonic chips shows a cooling of 3-4 °C.

µFluidic components (micro-pump, micro-valve and micro-connectors) were fabricated. Two novel pump concepts – a magnetically-driven shuttle pump and a solid state thermoelectrically-driven pump – have been successfully prototyped. Microchannel arrays with microfluidic chain consisting of micro-pumps and valves have been successfully integrated both in chips emulating laser structure sand the photonic integrated devices.

Chips emulating photonic integrated circuits with heaters and integrated micro-thermoelectric coolers were fabricated. Innovative schemes were devised for depositing and etching of AlN thin films, thereby paving a way for the industrial scale-up of the technology.

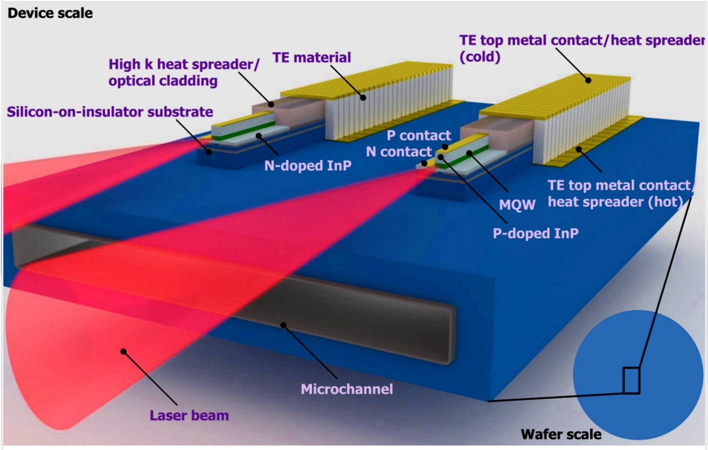
After the fabrication and characterisation of the photonic devices integrated with the subsystems, packaging of those devices were carried out. Design, assembly and characterization of the photonic

packaging for state-of-the-art photonic integrated chips were done as a benchmark for the advanced photonic integrated chip that includes heterogeneously integrated micro-thermoelectric coolers and micro-fluidics. The packaging designs incorporated OOK and PDM-QPSK packages. O-band OOK transmitter photonics integrated chips and C-band BPSK transmitter has been successfully packaged and validated in an error-free system transmission tests. One C-band PDM-QPSK transmitter PIC has been successfully packaged and been validated in the system transmission tests. A thermal PDM-QPSK Tx photonics integrated chip has been successfully integrated with a micro-fluidic manifold.
So far there have been 73 publications and 7 patent applications being filed. In addition, TIPS developed novel demonstrators, where LioniX successfully integrated InP chips with their Triplex platform to realize a narrow band tunable laser-source.

Innowacyjność oraz oczekiwany potencjalny wpływ (w tym dotychczasowe znaczenie społeczno-gospodarcze i szersze implikacje społeczne projektu)

The thermal challenge in electronics and photonics grows with ever-increasing levels of integration, as the designer struggles to build more functionality into shrinking package space. Packing so much functionality into smaller package footprints will lead to substantially increased thermal densities which in turn will require deployment of new thermal solutions.
TIPS is meeting this challenge by taking optoelectronic system thermal management beyond the state-of-the-art by developing technologies that will allow system designers to develop highly integrated 3D optoelectronic systems based on silicon.
Socio-economic impact:
Integrating photonic and electronic circuits in a single chip is a big challenge and it will reduce the cost, space and power consumption. The thermal issues have been addressed in the realm of TIPS, which will lead to a major technological development in handling internet data traffic expected to increase sharply (40-80x by 2020).
The greatly enhanced thermal performance of μTEC and μFluidic cooling will underpin higher density, lower cost PIC devices. The expected result of this work is a significant reduction in the electrical power consumed by a PIC package in performing its function, lowering environmental impact or increasing performance per unit cost. When demonstrated, this integration technology can be applied not only for photonic circuits, but also for the whole electronic industry, where the local thermal management is needed.
Wider Societal implication:
Higher performance, energy-efficient PICs will enable widespread, cost-effective roll-out of higher speed communications infrastructure, with associated societal and economic benefits. Localized thermal management should result in lower power consumption, in higher device density on the circuits, and in further miniaturization of the photonic and electronic devices. A significant reduction in power consumption in a widely used photonic device will lead to a reduction in the running costs for data/telecom systems. Reduced power consumption lowers the environmental impact of these systems or allows more performance for a given cost. Enhanced broadband speed and quality will eventually lead to several new services such as e-health (real-time doctor-to-patient communication),

e-learning (remote access to live lectures and self-paced tuition) and far better online delivery of products thereby significant cost saving and customer satisfaction.



TIPS concept

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