TECHNICAL REVIEW REPORT

Information and Communication Technologies
ICT

Project acronym:	NAVOLCHI
Project title:	Nano Scale Disruptive Silicon-Plasmonic Platform for Chip-to-Chip Interconnection
Grant agreement number:	288869
Funding scheme:	STREP
Project starting date:	01/11/2011
Project duration:	36 months
Coordinator:	KIT – Karlsruhe Institute of Technology
Project web site:	www.navolchi.eu

Period covered by the report:	Period No. 1 (from 01/11/2011 to 01/11/2012) (intermediate review during the period)
Place of review meeting:	Brussels
Date of review meeting:	27/11/2012
Experts:	Andrew Shields, Toshiba Research Europe, Cambridge Raimondas Petruskevicius, Center for Physical Sciences and Technology, Vilnius
Project officer:	Michael Hohenbichler

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Individual report	☐
Consolidated report	☒

SEVENTH FRAMEWORK PROGRAMME

European Commission
Information Society and Media

1. OVERALL ASSESSMENT

a. Executive summary

Please give your overall assessment of the project, commenting on the following:
- *main scientific/technological achievements of the project*
- *quality of the results*
- *attainment of the objectives and milestones for the period*
- *adherence to the workplan, any deviations (whether justified) and remedies (whether acceptable)*
- *take-up of the recommendations from the previous review (if applicable)*
- *contribution to the state of the art*
- *use of resources*
- *impact*

The strategic objective (enabling a high-bandwidth / low power / small footprint chip-to-chip interconnect, integrated on silicon) remains of high importance for future CMOS electronics. The NAVOLCHI approach promises, in the long term, clear advantages to more conventional optical or electrical interconnect solutions by combining their respective advantages, i.e. the small footprint of electronics with the high throughput / low power / short transmission delay of optical solutions. However, these advantages still need to be elaborated more clearly at a quantitative level and from a systems perspective.

Good progress has been made in the first year, notably in design and simulation of the basic devices, including estimation of the related device parameters.

A number of very promising new device concepts (metallo-dielectric laser, phase-modulator, q-dot based plasmonic amplifier) have been presented that are offering very interesting performances. However, for limiting the risks, also the initial [plasmonic] laser and [absorption] modulator concepts will be pursued as back-up solutions. The amplifier will provide a back-up solution in case that the overall transmission losses are getting to high for the targeted transmission speed.

In accordance with the task scheduling, work on transmitter side is more advanced than on receiver side.

Overall the project appears to be well planned and organised.

b. Recommendations concerning the period under review

Please give your recommendations on the acceptance or rejection of resources, work done and required corrective actions – e.g., resubmission of reports or deliverables, further justifications, etc.

1. Elaborate more clearly and in a more quantified way, the decisive advantages of NAVOLCHI at both device and system level in comparison to more conventional (electrical and optical) approaches. Distinguish between targets that are planned to be demonstrated inside the project, and possible further scaling and extrapolation beyond the term of the project.
2. Specify more clearly how the new phase-modulator will be used in the system and what the implications are at a system level.
3. Clarify the planned and further expected level of device integration, i.e. which system components (including the electronic ones) will be integrated together on the same piece of silicon in the planned system demonstrator, and what is the expected further potential for device integration. Are there essential practical reasons that could limit the useful degree of device integration?

4. Provice more complete component and systems specifications including e.g. device areas, thickness of the metallic layers, the planned number of parallel channels and total data rate. Systems specs should be linked clearly to the related component specs. Clarify the planned level of device integration. Investigate also the relevant parasitics such as thermal effects and crosstalk.
5. Provide a clear motivation for the intensive study of a q-dot based plasmonic amplifier in the optical spectral range and its impact for plasmons amplification in the telecom spectral range which is the working wavelength of the planned devices.

The answers should be provided in appropriate documents for the next review (i.e. in deliverables / reports planned anyhow or in specific document(s)).

c. Recommendations concerning future work

Please give your recommendations – e.g., overall modifications, corrective actions at WP level, re-tuning of the objectives to optimise the impact or to keep up with the state of the art, better use of resources, re-focusing, etc. Where appropriate, indicate the timescale for implementation.

1. Juerg Leuthold (overall project coordinator) will move to ETH Zürich next March. Details of his further involvement in the project, the possible implications on the project and on the grant agreement need to be clarified as soon as possible.
2. In future review meeting, include in the overview presentations also a brief follow-up of the previous review recommendations.
3. Start soon with planning the next review date.
4. Check that all the relevant documents are delivered to the EC and the reviewers before the meeting.

d. Assessment

☐ Excellent progress (the project has fully achieved its objectives and technical goals for the period and has even exceeded expectations).

X Good progress (the project has achieved most of its objectives and technical goals for the period with relatively minor deviations).

☐ Acceptable progress (the project has achieved some of its objectives; however, corrective action will be required).

☐ Unsatisfactory progress (the project has failed to achieve key objectives and/or is not at all on schedule).

2. OBJECTIVES and WORKPLAN

a. Progress towards project objectives

Assess to what extent the objectives of the project for the period have been achieved. In particular, please indicate if the project as a whole has been making satisfactory progress in relation to the Description of Work (Annex I to the grant agreement) and comment on the interaction between the work packages and the level of integration demonstrated.

The first year of the project has concentrated on specifying the targeted system and device performances. Good progress has been made, notably in the design and simulation of the individual components, such as the metallo-dielectric laser, plasmonic phase-modulator and q-dot based plasmonic amplifier. Preliminary experimental work is underway on these. As such the consortium is well placed to make a leading contribution to the development of plasmonic devices internationally. The partners seem to be working well together and several collaborations are evident within the consortium.

b. Progress in individual work packages

For each work package (WP), assess the progress in relation to the Description of Work (Annex I of the grant agreement). Please also report and comment on any delays, reasons for them and any remedial action taken. Specify the work packages concerned.

WP1: Management
This is discussed in Section 4 below.

WP2: Definitions and Specifications of Plasmonic Chip-to-Chip Interconnection Platform
This WP defines the targeted performance of the interconnect system and its plasmonic components. As such it has been one of the most important and active WPs in the first 12 months of the project.

The system targets stated in the meeting (data rate 7.2 Gb/s, latency<8.88ns @ 450MHz, power consumption <15 pJ/bit) are similar to the current state of the art for current electrical interconnects. The coordinator has clarified after the review meeting that the 7.2 Gb/s relate to single-channel transmission. Higher date rates will be achieved by using multiple parallel channels. However, the related details of the planned system demonstrator are not clear yet. Although these targets will not extend the state-of-the-art at a system level, it is nevertheless an ambitious and worthwhile challenge to develop fully functional interconnection technology based on plasmonics within the project.

Another important system attribute is the physical area of the interconnect system. This is defined rather vaguely in WP2 as "sub-wavelength". Given that realising a small footprint is one of the main motivations for developing plasmonic devices, the project goal in this regard should be defined more clearly (eg in m^2) and a detailed comparison to the state-of-the-art given.

Other important considerations, such as cross-talk, device heating and thickness of metal layer for waveguide couplers and modulator, which were mentioned in the meeting, have not been discussed in detail in the specifications.

While the system targets have been defined from an analysis of the current state of the art, the targets for the individual components are derived from considering their respective technological limitations. It is not entirely clear therefore how the individual device targets will translate to the overall system objectives.

We recommend that the project should provide a clear vision of how plasmonics will disrupt current technology beyond the timeframe of the current project. In order to be successful, plasmonic technology must overcome the best features of electrical interconnect technology (small device size etc) AND the best features of optical interconnect technology (bandwidth, power consumption etc).

WP3: Plasmonic Transmitter
The first twelve months have involved considerable modelling of laser and modulator structures. It has been decided to focus upon a metallo-dielectric nano-laser system, rather than the plasmonic laser originally demonstrated by TuE, as it has lower optical loss. This device looks very encouraging and first steps towards fabricating the devices have been taken. Two different modulator structures have also been considered and a decision made to persue the phase modulator structure. It was not clear to the reviewers how the phase modulator operates in detail.

WP4: Plasmonic Receiver
In accordance with the project plan this WP is at an earlier stage of development compared to WP3, with no milestones or deliverables in the reporting period. Nevertheless the presentation at the review meeting demonstrated that interesting progress has been made with the colloidal quantum dot plasmonic amplifier structure. Future work should focus on the target wavelength of 1550nm. However, a lot of efforts spent and results provided for plasmons gain in optical spectral range at 600nm (D1.4, MS16), which is not compatible with silicon photonics. Silicon is nontransparent at this wavelength. The focus of this project is on devices working in telecom spectral range at 1550nm. The motivation of this research should be provided.

WP5: Optical and Electrical Interfaces for Plasmonic Interconnection Platform
Very interesting progress has been made on coupling Si waveguides to a plasmonic waveguide. Preliminary measurements report low coupling losses. Optical beam steerers and filters have been designed.

WP6: Integration, Characterisation, Testing
This WP is in a preliminary stage in accordance with the work plan. It would be helpful to clarify the planned and further expected level of device integration, i.e. which system components (including the electronic ones) will be integrated together on the same piece of silicon in the planned system demonstrator, and what is the expected further potential for device integration. Are there essential practical reasons that could limit the useful degree of device integration?

WP7: Dissemination
This is discussed in Section 5 below.

c. Milestones and deliverables

Indicate whether the planned milestones and deliverables have been achieved for the reporting period (please give more detailed comments first and then fill in the summary table below).

There was some confusion surrounding the delivery of the project reports. The reviewers were supplied with the milestone and deliverable documents up to month 9 before the review meeting on 27 Nov 2012, in accordance with the fact that this is a nine month review meeting. However, since the project documents up to month 9 were limited in number, and (in the case of MS2) inadequate, it was decided to include all the project documents up to month 12 in the review. The reviewers were subsequently sent the deliverables for months 9 to 12, and these have been included in the review. The reviewers were not sent the milestones due in this period (MS10, 16, 17, 26, 27, 28, 37) but were able to review these online.

In general, the standard of the documents was good, with the exception of MS2 concerning the specification of the plasmonic devices to be developed. Most of the specifications stated here are inadequate to define the corresponding devices and many are not even dimensionally correct. It should be noted, however, that MS2 has been superseded in D2.1, which shares the same title and is a considerable improvement. It is therefore not necessary to resubmit MS2. It was unfortunate that only MS2 (and not D2.1) was available to the reviewers before the review meeting.

STATUS OF DELIVERABLES			
No.	**Title**	**Status** *(Approved/Rejected)*	**Remarks**
D1.1	Project website	Approved	
D1.2	Project reference online manual	Approved	Condensed version of Annex II and Consortium Agreement
D1.3	Project quality online assurance manual	Approved	A useful document summarising procedures for D, MS, prototypes
D1.4	Intermediate progress report	Approved	First 9 months
D2.1	Definition of chip to chip interconnection system environment and specification (3)	Approved	Submitted D2.1 has different title to the DoW, but close to the expected content. It does not adequately discuss the potential impact of plasmonic technology.
D2.2	Definition of plasmonic devices (12)	Approved	Specifications of the various devices to be fabricated. Not clear how these relate to the system level goals.
D3.1	Report on optimised structure for metallic/plasmonic nanolaser and its coupling to Si WGs (12)	Approved	
D3.2	Report on modelling of the modulator structure (12)	Approved	
D5.1	DDCM specification document (6)	Approved	
D5.2	DDCM with electrical PHY design and verification data base (12)	Approved	

STATUS OF MILESTONES			
No.	**Title**	**Status** *(Approved/Rejected)*	**Remarks**
MS1	Definition of chip to chip interconnection system environment and specification (3)	Achieved	This MS is identical to D2.1
MS2	Definition of plasmonic devices and material properties for chip to chip interconnection (6)	Achieved according to D2.2	Milestone report MS2 has been superseded by D2.2 which is a considerable improvement.
MS8	Decision on an optimised structure for metallic/plasmonic nano-laser and its coupling to Si waveguide (6)	Achieved	Superseded by D3.1
MS9	Decision on a optimised structure for plasmonic modulator (6)	Achieved	
MS10	Grown wafer structure for plasmonic lasers (12)	Achieved	

MS16	Demonstration of decision on optimised structures for plasmonic amplifiers (12)	Achieved	Not clear how plasmonic amplification at 600nm related to project goals.
MS17	Synthesis of nanopartictles with gain at 1550nm (12)	Achieved	
MS25	Decision on optimised plasmonic waveguide couplers (6)	Achieved	
MS26	Fabrication of plasmonic waveguide couplers with less than 3dB coupling loss (12)	Achieved	
MS27	Design of first generation beam shapers and compact optical filters (12)	Achieved	
MS28	DDCM with electrical PHY design and verification (12)	Achieved	
MS37	Plasmonic active device characterisation results (12)	Achieved	
MS44	Dissemination of activities in the project website and continuous update (1)	Approved	
MS45	Press release on start of project to the public demonstrated (2)	Approved	

d. Relevance of objectives

Indicate whether the objectives for the coming periods are (i) still relevant and (ii) still achievable within the time and resources available to the project. Assess also whether the approach and methodology continue to be relevant.

The overall objectives of the project of developing small footprint, low power, high bandwidth chip to chip interconnects are still very relevant and important. The consortium has decided to focus on particular device designs, such as the metallo-dielectric laser and SPP phase modulator. The decisions are carefully argued and the respective device targets seem achievable.

e. For Networks of Excellence (NoEs) only

Assess how the Joint Programme of Activities has been realised for the period and whether all the planned activities have been satisfactorily completed.

n/a

3. RESOURCES

a. Assessment of the use of resources

Comment on the use of resources, i.e. personnel resources and other major cost items. In particular, indicate whether the resources have been utilised (i) to achieve the progress and (ii) in a manner consistent with the principle of economy, efficiency and effectiveness[1]. Note that both aspects (i) and (ii) have to be covered in your answer. The assessment should cover the deployment of resources overall and by each participant. Are the resources used appropriate and necessary for the work performed and commensurate with the results achieved? Are the major cost items appropriate? In your assessment, consider the person months, equipment, subcontracting, consumables and travel.

The use of resources has not been assessed in detail in this intermediate review.

b. Deviations

If applicable, please comment on major deviations with respect to the planned resources.

KIT has under-spent significantly in the first year. However this was explained by delays in the hiring of project-specific staff, while the intermediate gap has been filled with available staff for which no cost will be charged

[1] "The principle of economy, efficiency and effectiveness refers to the standard of "good housekeeping" in spending public money effectively. Economy can be understood as minimising the costs of resources used for an activity (input), having regard to the appropriate quality and can be linked to efficiency, which is the relationship between the outputs and the resources used to produce them. Effectiveness is concerned with measuring the extent to which the objectives have been achieved and the relationship between the intended impact and the actual impact of an activity. Cost effectiveness means the relationship between project costs and outcomes, expressed as costs per unit of outcome achieved." Guide to Financial Issues, Version 02/04/2009, p.33.

4. MANAGEMENT, COLLABORATION AND BENEFICIARIES' ROLES

a. Technical, administrative and financial management of the project

Assess the quality and effectiveness of the project management, including the management of individual work packages, the handling of any problems and the implementation of previous review recommendations. Comment also on the quality and completeness of information and documentation.

An appropriate management structure for the project has been established. Guidelines have been put in place for the implementation of the project plan, as well as the preparation of the project milestones and deliverables. However, the process for the delivery of the project documents to the EC and the reviewers (see comments above) could be improved.

b. Collaboration and communication

Comment on the quality and effectiveness of the collaboration and communication between the beneficiaries.

There has been good communication between the partners with 3 face to face meeting and 10 telephone meetings. There is appropriate collaboration between the partners in the various workpackages.

c. Beneficiaries' roles

Give an assessment of the role and contribution of each individual beneficiary and indicate if there is any evidence of underperformance, lack of commitment or change of interest.

The individual beneficiaries are well suited and committed to their tasks in the project.

5. USE AND DISSEMINATION OF FOREGROUND

a. Impact

Is there evidence that the project has so far had, and is it likely to have, significant scientific, technical, commercial, social or environmental impact (where applicable)?

The project is still in an early stage to define real impact of its developments.

b. Use of results

Comment on whether the plan for the use of foreground, including any updates, is still appropriate. Comment also on the plan for the exploitation and use of foreground for the consortium as a whole, or for individual beneficiaries or groups of beneficiaries, and its progress to date.

The plan for use of foreground is unaltered and still appropriate. Two patents have been filed, or are in the process of being filed, by the consortium

c. Dissemination

Assess whether the dissemination of project results and information (via the project website, publications, conferences, etc.) has been adequate and appropriate.

The consortium have set up a project website containing general information. They also made a press release at the start of the project and have printed a project leaflet for distribution at conferences and trade fairs. There have been 5 journal papers and 23 conference papers within the reporting period.

d. Involvement of potential users and stakeholders

Indicate whether potential users and other stakeholders (outside the consortium) are suitably involved (if applicable).

The project is still in an early phase and so contact to potential users has been limited so far.

e. Links with other projects and programmes

Comment on the consortium's interaction with other related Framework Programme projects and other national/international R&D programmes and standardisation bodies (if relevant).

A workshop was held by the NAVOLCHI consortium at the ICTON 2012 conference in Warwick. This also involved another EU project in this area PLATON.

6. OTHER ISSUES

If applicable, comment on whether other relevant issues (e.g. ethical issues, policy/regulatory issues, safety issues) have been handled appropriately.

None to report

Name(s) of expert(s):
Date:
Signature(s):