SIXTH FRAMEWORK PROGRAMME PRIORITY:

IST FET Open

MEGAFRAME

Million Frame Per Second, Time-Correlated Single Photon Camera

Publishable Executive Summary

Deliverable Version:	1.0
Nature:	*Report*
Report Preparation Date:	5/7/2007
Dissemination level:	*Public*
Contract Start Date:	01.06.2006
Duration:	36 Months

Information Society Technologies

Publishable executive summary

Project's Objectives:

Imaging of ultra-fast, time-correlated, molecular processes in physics and the life sciences is placing increased demands on camera technology. A new detection paradigm is necessary whereby a solid-state sensor array of pixels sensitive to a single photon is assembled. Pixels composed of detectors called Single Photon Avalanche Diodes (SPADs) will be integrated for the first time in an advanced, deep-sub-micron CMOS process. Large arrays of SPADs interfacing to networks of parallel digital processing units on the same chip will provide record levels of timing accuracy, sensitivity and speed.

The ***MEGAFRAME*** 128x128 pixel prototype will be capable of a sustained 1,000,000 frames per second with 50 picoseconds time uncertainty. This will re-establish European excellence in the field of ultra-high speed video capture. To access and process the extremely high data rates generated by the pixel array, novel system architectures must be developed. Another essential advance is a highly reproducible optical concentrator array to reclaim the fill-factor lost to pixel-level infrastructure.

The new imaging system will be evaluated using emerging time-correlated methods such as Fluorescence Lifetime Imaging Microscopy and Correlation Spectroscopy, and Forster Resonance Energy Transfer. Resolutions and frame rates at least ten times higher than today's solutions will be achieved. Mechanisms such as calcium signalling will be monitored on single cells at 1 microsecond steps for the first time. Future advances in proteomics, systems biology and drug discovery are dependent on such improved understanding of intra-cellular processes.

Major contributions to multi-processing architecture, flow-control engineering and fast phenomena observation are also expected. The consortium is a unique combination of imaging technology innovators, a leading European semiconductor manufacturer and a diverse end-user community from the life sciences, physics and chemistry.

First Year Activities:

Since the submission of the proposal, the partners have enhanced and accelerated their existing SPAD related research programmes. New MEGAFRAME specific programmes have also been initiated and aggressively implemented. Most of the corresponding developments are briefly summarised on the project's Website.

A new and refined search on recent scientific articles, other developments of potential interest and an extensive patent search have been carried out by each partner in the respective domains of competence. Although the field of single photon based arrays and imagers is attracting increased attention, no new element has emerged that may impair the adequacy and the timeliness of the proposed developments (for example, there is little obvious patented activity on high speed imaging and no patents on integrated imaging systems based on SPADs).

The previously described information has been used by the partners to revise the design specifications. Most of the original approaches were confirmed as viable, and the corresponding performance as satisfactory.

Following this preliminary activity, in the first year of MEGAFRAME we implemented the building blocks of the project, i.e. a working design for the single photon detectors implemented in 130nm CMOS process, and a working analog and digital pixel design. With a working pixel it is now possible to proceed to the next step, the design of a fully functional 32x32 pixel array. This design, in turn, will be the building block of the second and final design, a 128x128 pixel array.

During this first year, we also made progress in the design of the overall architecture of the first sensor stressing scalability, bearing in mind the final prototype. An innovative optical system has also been extensively simulated and designed, with results clearly suggesting that the target of a >20x recovery of power is realistic and feasible. The optical concentrator is on track to fabrication; preliminary findings are positive and encouraging.

We have also increased our level of familiarity with time-correlated single photon counting techniques applied to biologically relevant materials and samples as well as optical setups used in the life sciences and medical imaging domains.

We believe that the level of innovation introduced by the components we have studied and implemented is very high. Based on the project's first year results, we do also believe that it will be possible to achieve the ultimate goals of MEGAFRAME.

Contractors:

Name	Short name
Ecole Polytechnique Fédérale de Lausanne, Lausanne, CH Quantum Architecture Group (AQUA), Processor Architecture Laboratory (LAP), School of Computer and Communications Sciences	EPFL
Università di Pavia, Pavia, I Optoelectronics Group, Department of Electronics, Faculty of Engineering	UNIPV
University of Edinburgh, Edinburgh, UK Institute of Micro and Nano Systems (IMNS), School of Engineering and Electronics Collaborative Optical Spectroscopy, Micromanipulation and Imaging Centre (COSMIC)	UNIED
Fondazione Bruno Kessler (formerly Istituto Trentino di Cultura), Trento, I Integrated Optical Sensors Group, Microsystems Division, Center for Scientific and Technological Research	FBK/ITC
ST Microelectronics (R&D) Limited, Edinburgh, UK Imaging Division	STMICRO

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