

Towards a Research Pole in Photonics in Western Romania

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ABSTRACT

We present our efforts in establishing a Research Pole in Photonics in the future Arad-Timisoara metropolitan area projected to unite two major cities of Western Romania. Research objectives and related training activities of various institutions and groups that are involved are presented in their evolution during the last decade. The multi-disciplinary consortium consists principally of two universities, UAVA (*Aurel Vlaicu* University of Arad) and UMF (*Victor Babes* Medicine and Pharmacy University of Timisoara), but also of the Arad County Emergency University Hospital and several innovative SMEs, such as Bioclinica S.A. (the largest array of medical analysis labs in the region) and Inteliform S.R.L. (a competitive SME focused on mechatronics and mechanical engineering). A brief survey of the individual and joint projects of these institutions is presented, together with their teaching activities at graduate and undergraduate level. The research Pole collaborates in R&D, training and education in biomedical imaging with universities in USA and Europe. Collaborative activities, mainly on Optical Coherence Tomography (OCT) projects are presented in a multi-disciplinary approach that includes optomechatronics, precision mechanics and optics, dentistry, medicine, and biology.

Keywords: Research pole, photonics, training, optical coherence tomography, optomechatronics, optical devices, optical metrology, dentistry, laser treatments, gastroenterology, manufacturing, precision mechanics, micro-mechanics.

1. INTRODUCTION

Optics has always been a fascinating domain to approach, as light is a major component of human life. Thus, light and vision to begin with, then instrumentation and nowadays Photonics with so many applications hardly to present in this limited space represent fields that no scientist can miss.

The path towards an optics education and why not a career, has at least three possible starting points: Physics, Electrical and Mechanical Engineering. Of course, these are not exclusive, as Biology and Medicine are also now very much into this equation, as we shall see in this presentation as well.

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Fine (or precision) mechanics has been particularly dedicated to optics education & research in Romania. While in the capital city of Bucharest it started in what is now UPB – the „Politehnica” University of Bucharest, in the Western (industrialized) part of the country this development was mirrored some years later, when this domain was opened at what is now UPT – the „Politehnica” University of Timisoara, in close connection with industry development, IOT (Optical Enterprise Timisoara). This started as a branch of IOR (The Romanian Optical Enterprise), the „mother” company in Bucharest.

Both industry, education and R&D in Fine Mechanics and Optics flourished until the 1989 Revolution changed conditions again. Communism fell and democracy (with the specific transition towards it) was installed; universities developed freely trying to find their place in a society that was itself rapidly (and sometimes chaotically) changing. In a few years only, the „big” centralized (state) industry fell and SMEs (Small and Medium Enterprises) took over the void left places. Technical universities had to make efforts to adapt, as until then, the engineering education and R&D activities (with their related funding) were being carried out in relationship with the „big” industry. In parallel, the number of related State Research Institutes has also decreased considerably in the 90s.

Research Grants begun in 1998 (but a National R&D Plan was issued only in 2002) to replace the old centralized system of contracts that was in place between industry, universities, and research institutes before 1989 (while some of the former Institutes’ staff was naturally „absorbed” by universities). SMEs have also grown in the meanwhile. Thus, a new, at first timid development began for the universities and for the related industry, after more than a decade of searches for a new system to fit in, this happened not only for the technical universities, but also for those which had only some departments focused on STEM – Science, Technology, Engineering and Mathematics. The EU (European Union) integration process that started in 2004 gave a boost to this process. Romania’s integration in the EU in 2007 accelerated it, although the poor use of the available EU funding was – and still is – a shortcoming that affects it seriously. So did the economic crises that, we may say, stopped the growth of both industry and universities for several years. Funding has been unusually abundant for 3-4 years (although the 1% of the National Product for Research, agreed with the EU, had not yet been reached). Then Europe entered into an economic crisis and the National Calls stopped for about 2 years. Priorities had to be set, which forced a new national Law of Education (and adjacent legislation) that lead to a much better (and long awaited) attention to be paid to competitiveness and real value. This also created premises for increased transparency in the system and set new, higher, more Western standards in promotion in both the universities and R&D sectors. Conditions were created for research grants to be awarded on true competitive grounds. The process is yet incomplete, as two obvious tendencies still manifest: the first one is to push the reform further, in all its ethical and efficiency aspects, while a second one is to go back to a system not awarding the best and prone to intervention.

In Optics, the domain has very much followed the general trend, in universities, R&D and industry. Thus, now there are several favorable conditions that are facilitating our initiative to establish a Photonics Pole in Western Romania, bringing together groups and institutions willing to participate:

- (a) There is a strong tendency towards Photonics, Optomechanics and Optomechatronics developments in the area (coupled with the one at an international level), in conjunction with inter-disciplinary approaches, that include by example different areas of medicine;
- (b) There is a process of significant growth of Romanian universities, with developing links with universities in Europe (especially after Romania joined the EU), but also in the US and in other parts of the world.
- (c) The new project of Romanian regions and with the long time planned metropolitan area that is designed to unite the two major cities in Western Romania, Arad and Timisoara (which are less than 50 km apart), make the project of this Photonics Pole in the region more feasible;
- (d) It is necessary to develop both the R&D capabilities of the universities (and a stronger competition now exist between them in this direction), of the companies (and there are competition calls on EU funding in this specific direction), as well as of their collaborative links.

To follow these strategic lines, we have proposed and are currently working on a Partnership Project (1682/2011), funded by the Romanian Authority for Scientific Research – project that has several months of implementation now. It includes five institutions (Fig. 1) focused on different domains, in a complementarity that is intended to be the basic structure of the future Photonics Pole, as we shall present in the following. The links with other national and international collaborators will also be presented, as an intensification of these interaction is an essential part of our strategy.

All these aspects raise specific issues that need to be solved, and this presentation points out some of our collaborative efforts to:

- (i) *achieve high quality research, with international impact;*
- (ii) *direct the training of postgraduate (PG) students towards the most challenging and rewarding topics – while providing them with the proper international standards – for both research and publishing;*
- (iii) *interact in a productive way with the industry and satisfy their demands – mainly on a national and regional level (which is an on-going demand, as pointed out previously);*
- (iv) *shape the undergraduate students (UG) curricula to sustain the goals presented above, while also providing them with the basic knowledge to be able to be integrated in their professional environment, but in an innovative and thus competitive way. This is a major scope of the activity regardless of the area of the students (as in our Consortium we have both UG and PG students from areas as diverse as Mechanical Engineering, Automation, Medicine and Dentistry).*
- (v) *interact with research active institutions abroad that can inspire and educate the staff of the Pole.*

As one may remark, our approach is top-down, from the highest output, in R&D (and its requirements), to the very basic aspects of higher education. Thus, *the scope of this paper is to present the challenges we are facing and some of our solutions for achieving these goals.*

2. ACADEMIC AND INDUSTRIAL PARTNERS

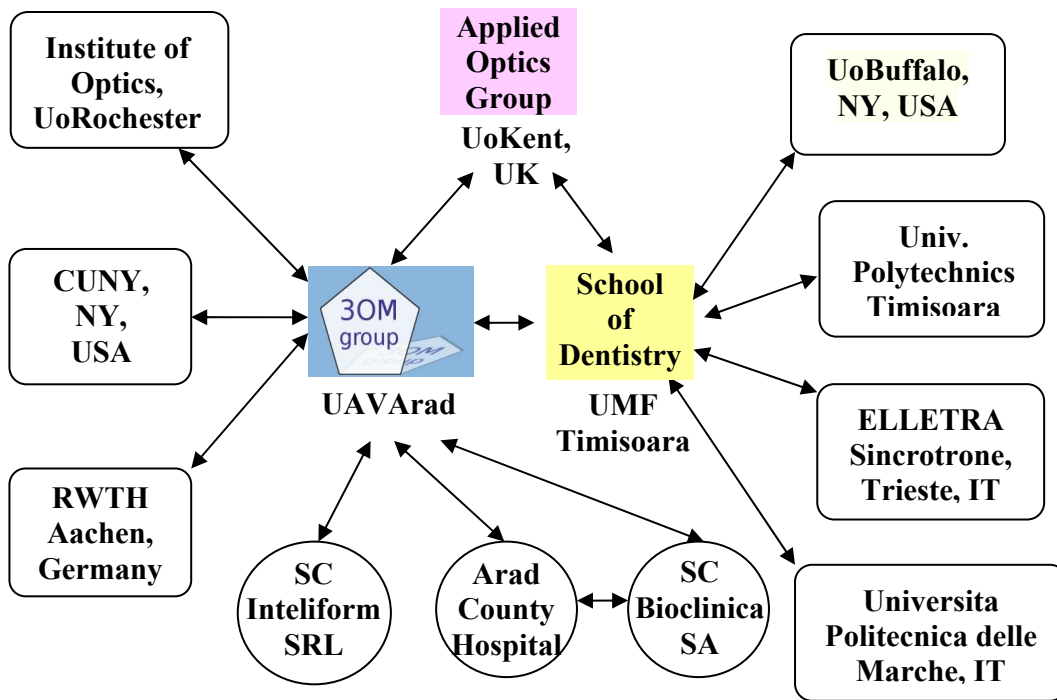


Figure 1. Members of our Consortium and some of their collaborative links. Member institutions from the academia are marked with rectangles, while industrial and medical partners are marked with circles. The central part of the figure comprises the future planned Photonics Pole in Western Romania.

Our Consortium, which we make efforts to continuously expand, now comprises several institutions (Fig. 1). It has been built on an initial collaboration between three groups, located in three universities:

- (1) **The Applied Optics Group (AOG)** of the University of Kent at Canterbury (UoKent), UK [1], led by Professor A. Gh. Podoleanu, with expertise in Optics and Photonics, focused on Biomedical Imaging and more specifically on Optical Coherence Tomography (OCT);
- (2) **The Imaging Group** [2] of the School of Dentistry, *Victor Babes* Medicine and Pharmacy University of Timisoara, active, besides the Medical fields, in various areas of Biomedical Imaging applied for Dentistry, but also for other fields such as Materials Studies, including OCT;
- (3) **The 3OM Group (in Optomechatronics, Optical Metrology, Optics & Mechanics)** [3], School of Engineering, *Aurel Vlaicu* University of Arad, group established more recently, in 2008 and led by Prof. V.F. Duma, PI of our current Partnership Project [4] on which we are trying to put a base to the Photonics Pole in Western Romania.

The industrial and medical partners of our Consortium are also pointed out in Fig. 1 (in circles), while some of our most important collaborators are also shown, in rectangles, with only some of the current collaborative links that exist between them.

3. CURRENT PARTNERSHIP PROJECT

In Fig. 2 the general plan of the collaboration in the current project [4] is presented, with some of the tasks assigned to each institution. All of them imply both senior and young researchers. From more than 30 researchers currently involved in the project, almost half are PG and UG students – with the stress on the formers. This human resource that we try to keep balanced is enhanced by the researchers and PG students that are working occasionally on the topics approached by our collaborators (Fig. 1), so the number of people involved is actually variable every month.

The training of these PGs is therefore a challenge [5], especially since they have to move occasionally from one institution to another, and there are various aspects they have to approach by working in small groups at a time. These aspects are covered normally by the coordinator of the project at each institution, but even that has in this case not proved sufficient, and therefore we have designated actually a deputy for each coordinator to be able to face the very diverse tasks that appear. For such a multidisciplinary work, one has to learn not only the scientific component, but also components related to the management of the activities – and this happens at all levels.

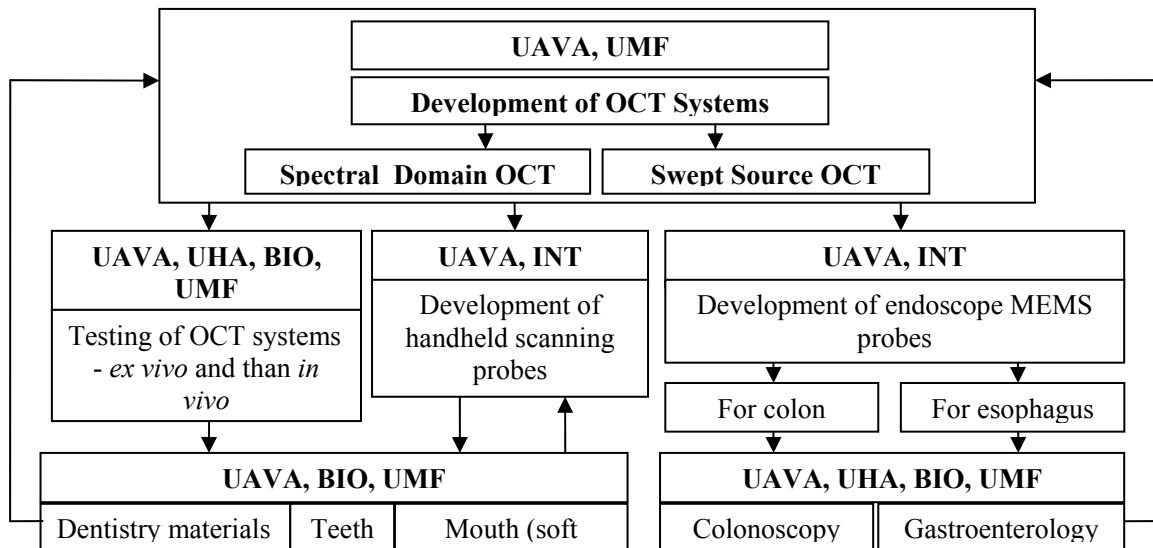


Figure 2. Scheme of the links between the Phases of our current Partnership Project [2] - with the partners involved: UAVA - Aurel Vlaicu University of Arad, UMF - Victor Babes Medicine and Pharmacy University of Timisoara, BIO - Biomedica S.A., UHA - University Emergency Hospital of the Arad County, INT - Inteliform S.R.L. Timisoara.

Although the project has started for less than a year, most of the PG and UG students involved have participated in a conference related to the topics approached – and this has been a specific part of our strategy for their development. For some of them (mainly for the UGs) attending this conference has been a very early research experience, while for some of them (even for some PGs) it was the first time that they participated in an international conference (the LASER Congress in Munchen was such a conference). This prepares the ground for more complete journal papers to conclude their various directions of work – from optomechanics to automation, medicine (endoscopy, gastroenterology) and dentistry (with various aspects, from materials studies in prosthetics to the imaging of the soft tissue of the mouth). It provides the students with a feedback on the level of their work, while also giving them the right image on what the (expected) level of the research is internationally. The three years time interval of the project are planned to allow for the complete development of each research theme, but we have verified in practice that a good start is a must for success.

Another most interesting aspect of PG training in our Consortium - particularly, but not only on this project – is the fact that the students (but the seniors as well) come into contact with aspects well outside their usual area of expertise. Thus, everyone has to learn and to expand his/her view to an inter-disciplinarity that may prove quite useful in their future or current career.

4. R&D, TRAINING AND TEACHING RELATED TO RESEARCH AT EACH PARTNER

- (a) **The 3OM Optomechanics Group** at the *Aurel Vlaicu* University of Arad. Our activity, mainly focused on Optomechanical devices and systems, is presented in detail in [6]. *These research directions* include:
- (i) *Optomechanical choppers* [7-9], for which we developed the analysis and design of classical chopper wheels with windows with linear edges [10], introduced and developed a new device, the “eclipse chopper”, with wheels with windows with semi-circular edges [11], built prototypes [12], and developed a program for their design (for top-hat, Gaussian and Bessel beams), to choose the parameters of the device in order to obtain a desired profile of the output laser impulses [13];
 - (ii) *Laser scanners: monogon* [7, 14, 15]; *polygonal* [14, 16], which we have analysed [17]; *galvanometer-based* [18, 19], for which we demonstrated [20, 21] the optimal scanning functions to be used (which has to be linear plus parabolic [20], not linear plus sinusoidal, as previously stated in literature [19]), and for which PG (and UG) students are working on a variety of topics including optimal control architecture [22, 23] and driving algorithms; *Risley prisms* [24-26], on which student projects are studying their exact patterns [27], as well as driving solutions;
 - (iii) Radiometry of optical systems [28], including optical attenuators [29], as well as colorimetry;
 - (iv) Optical metrology – for industrial measurements [30], with on-going UGs projects [15, 31];
 - (v) OCT [32, 33] and related subassemblies [34, 35] - including swept laser sources scanned in frequency [36-38], 2D scanners with galvoscaners [39-41] or with other 1-D devices [42, 43]), and the lateral scanning in OCT, for which we extracted the necessary rules of thumb to use optimally the GSs in OCT setups – and demonstrated that the most artifact-free images are obtained with triangular scanning [44].

For our current project we approach GS-based handheld probes [45], as well as endoscopic miniature scanning heads. Another research avenue is on the optimal scanning algorithms that have to be employed in OCT (but more general, in Biomedical Imaging) to obtain the most – in terms of speed (for *in vivo* real-time imaging) and artifact-free images – from the OCT systems. The translation of the research-gained expertise in UG teaching has been presented in detail in [5], while a most extended discussion on the methodological aspects has been done in [46].

- (b) **The Imaging Group** [2] of the School of Dentistry, Victor Babes Medicine and Pharmacy University of Timisoara is focused on several applications of biomedical imaging techniques for the study of both soft and hard tissue [47], as well as for prosthesis (Fig. 3) and materials used in dentistry. OCT investigations (with Time Domain and Spectral Domain systems) are also validated using other techniques, such as MicroCT (Computer Tomography) – in collaboration with Synchrotron-Radiation Elettra Trieste, X-rays and ultrasounds, but also with histopathological interpretations. The projects carried out, like our current one [4] involve PG training, while the research results are usually translated into UG teaching – with hands-on-experience.
- (c) **The Applied Optics Group (AOG)** of the University of Kent, UK [1], led by Professor A. Gh. Podoleanu has built up an international reputation based on its extensive publication record in the areas of theoretical and applied optics, and has attracted considerable funding from the EPSRC, BBSRC, Leverhulme Trust, ERC, EC, NIHR, Pfizer, OTI Inc. Canada, New York Eye and Ear Infirmary (NYEEI) and Innovative Small Instruments.

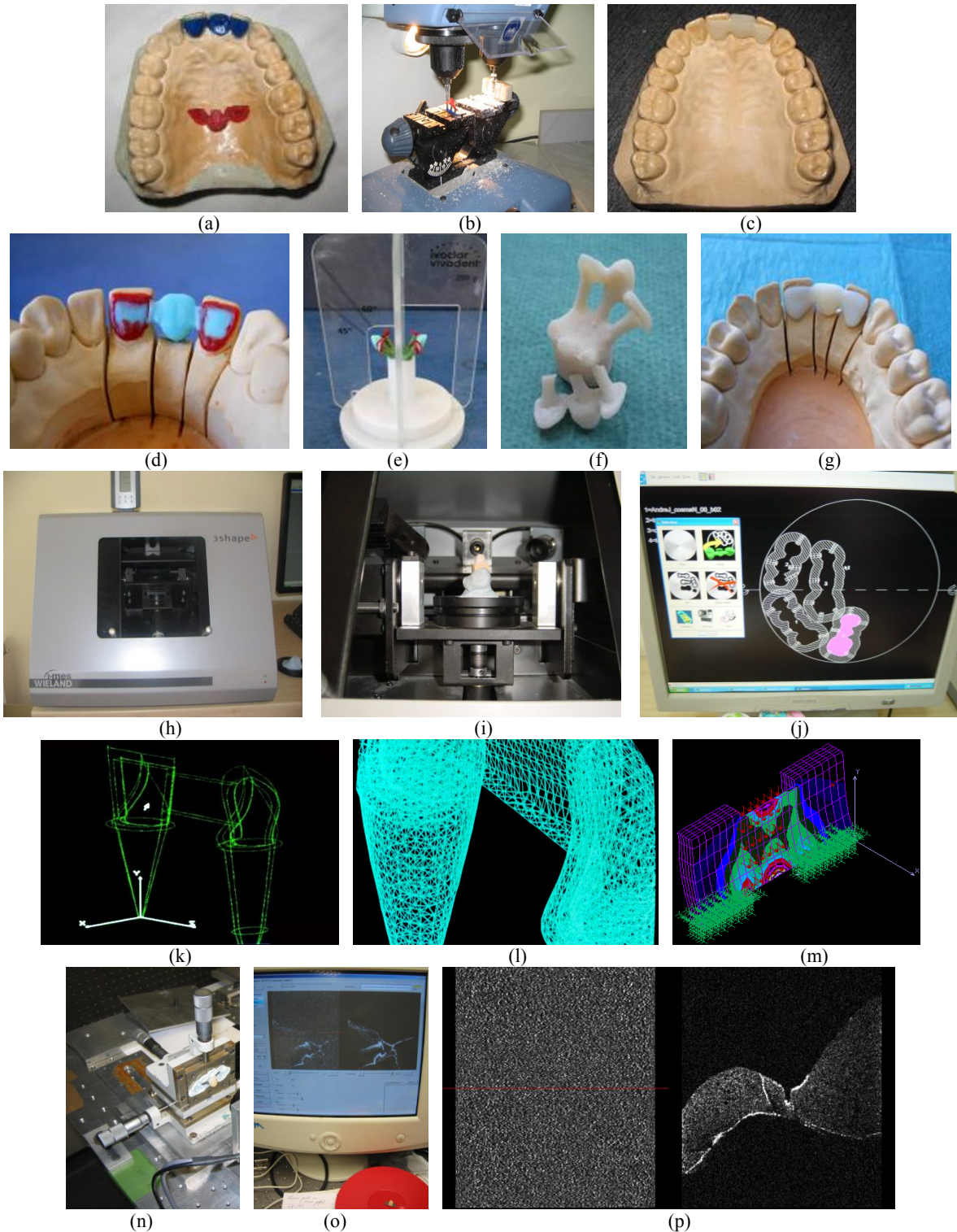


Figure 3. Technological approach of the fixed partial prosthesis: after modelling a RBFPD from a special composite resin (a) and the parallel mechanical milling by a dedicated system (Dakar) (b) in order to obtain the final aspect of the integral ceramic fixed partial prosthesis (c); wax modeling of RBFPD for the pressing technology (d); the wax infrastructure ready for investment (e) and pressing technology (f); CAD/CAM technology for the same integral ceramic fixed partial prosthesis (h, i, j); numeric simulations of the same integral ceramic bridge to observe the most tensioned area of the structure (k, l, m) and OCT investigation of the areas with the fracture line discovered inside the ceramic material.

The AOG has pioneered *en face* Optical Coherence Tomography (OCT) technology in 1996 and has produced the first OCT *en face* images from the retina, has researched and protected the generation of a combined OCT / confocal image [48], generated 3D images from retina and skin, devised multi-interferometer configurations and special modulators to collect simultaneously images from different depths in the tissue and introduced the concept of OCT imaging with adjustable depth resolution. AOG also performed theoretical studies on the performances of OCT systems. First images of eye with pathologies using *en-face* OCT have been reported. AOG has also developed the first instrument combining OCT with ICG fluorescence for imaging the retina in collaboration with New York Eye and Ear Infirmary and Ophthalmic Technology Inc. Combination of three technologies in one system, OCT, scanning laser ophthalmoscopy and adaptive optics and highest limit *in vivo* obtained in *en-face* images as thin as 3 μm were reported. Resources were oriented towards extending the expertise acquired from ophthalmology to cell imaging and OCT applicability to image embryos [49] and more recently, towards OCT endoscopy [45]. Expertise was extended to dentistry [47], to imaging of basal cell carcinoma and to art conservation [50]. Other current research focuses on a novel solutions to reject the effect of mirror terms in spectrometer based OCT [51], to eliminate the speckle in OCT, to perform 3D imaging using multiple paths configurations [52, 53], on coherence gated wavefront sensors [54] and on speeding up the acquisition based on graphics cards [55].

Professor Podoleanu has been involved in supervision of postdoctoral researchers constantly from 1999, with a number fluctuating, up to 5/year and of PhD students, with a number up to 8/year. He has created a new lecture course, required to be taught to students recruited by a Marie Curie Training site, HIRESONI (2006 – 20010) he has coordinated with two other universities and three companies in Europe, supported by the EC, *Biomedical Optic*. This is now being taught to other PhD students in the School of Physical Sciences in the UoKent. Research inspired undergraduate projects are conducted by the AOG with students from the 3rd year MSc (PH600) and 4th year MPhys (PH700) in the School of Physical Sciences. They cover several aspects of applied optics, such as designing hand held probes for imaging the eye, for imaging in the mouth, for endoscopy and addressing fundamental limits in the technology, such as devising simple methods for linearisation of data before FFT [56]. An applied optics project is conducted with students from the 3rd year Forensic Science programs on investigating the OCT as an anti-spoof tool in imaging fingerprint at security points. Other projects are conducted with students from other universities in the South East of England, supported for short summer projects by South East Physics Network (SEPNET), embracing assembly of optical configurations for OCT as well as devising customised LabView Matlab programmes for OCT interfaces. AOG is also regularly acting as host of Erasmus work placement students, sent by Universities in Brno, Lille and Porto for 3 – 10 months to develop practical skills in an optics lab. Such exchanges resulted in published results in journals [57] and several conferences.

(d) The Optical Diagnostics and Applications Lab (ODALab) [58], founded in 1994 by Professor Jannick Rolland, is today comprised of distributed labs. Its headquarter is at The Institute of Optics, University of Rochester (UoR), NY USA, and it has two satellite labs, one at the University of California at Los Angeles (UCLA), led by Dr. Anand Santhanam, and the other at Armstrong Atlantic University in Georgia, led by Dr. Felix Hamza-Lup. The research at UCLA focuses on Augmented Reality (AR) in the context on radiation oncology together with GPU-based processing for clinical translation, while the satellite lab in Armstrong Atlantic University focuses on undergraduate and master education in augmented reality, with a focus on haptic and networking AR. The research in the headquarter lab focused early on solely on novel head-worn displays for AR [59-61]. The ODALab conducted some of the first depth perception studies in AR environments published in the Journal *Presence: Teleoperators and Virtual Environments* (MIT Press) [62-64]. Around 2000, the research expanded to include research in optical imaging, such as in Optical Coherence Tomography (OCT). This area of research has bloomed to an active area of research in the ODALab, focused on instrumentation development for high lateral-resolution imaging across extended depth-of-focus via Bessel Beam Imaging [65] and Gabor Domain Optical Coherence Microscopy (GD-OCM) [66-72]. GD-OCM operates at higher numerical aperture than OCT, leverages liquid lens technology within a custom imaging microscope [67-68], and processes images using a Gabor-based fusion technique [69]. It achieves micrometer-class lateral resolution over up to two millimeter in depth for skin tissue [71-72]. The lab also focuses on advances in functional OCT such as Doppler OCT [73-74] and OCT elastography. The ODALab partners with Medical Centers to conduct research related to the upper airways, the human eye, skin and the oral cavity.

Since 2007, research in the ODALab started focused efforts in freeform optics driven by critical needs in compact and mobile instrumentation, specifically, in the applications of AR [75-76] and biomedical research. Several national and

international sponsors, collaborators and industrial partners participate in the research efforts. Support is given through grants from the National Science Foundation, the NYSTAR Foundation, the II-VI Foundation, government research labs and industry. As part of a growing interest in freeform optics [77], Prof. Rolland is currently the director of a planned NSF Center for Freeform Optics, collaboration between UoR and the University of North Carolina Charlotte.

In terms of UG students at the University of Rochester, there is a Journal of Undergraduate Research (JUR), entirely focused on publishing peer-review articles, from all domains, but only from UG students. Also, some half of the UG and most PG (Master) students are implied in research. Prof. Rolland, by example, is the Director of the *Robert E. Hopkins Center for Optical Design and Engineering* that was created to provide students with a computer lab, a fabrication lab, and a testing lab, that all, from UG to PG can access to develop hands on experience. Activities with the Center are integrated as part of lectures to provide a place for experiencing hands on learning. Also several classes have a lab component to give students hands-on experience with knowledge taught in the classroom.

Training of PG (Doctoral students, but also PostDocs and Master students) is an essential component of the ODALab activity, and the funding discussed previously is focused to support their activity. There are thus up to 20 young researchers at a time in Prof. Rolland's supervision – over half are Ph.D. students.

The collaboration of the Consortium with ODALab has started in 2009, when Prof. Duma (UAVA) was a Fulbright Senior Research Fellow at The Institute of Optics, University of Rochester, in Sept. 2009-June 2010. It continues on issues of scanning in OCT [35], especially for galvoscaners [44], as well as on various problems of optical engineering.

(e) **The Nanofabrication Facility at the Grove School of Engineering of the City University of New York (CUNY), NY, USA.**

The activity in the Nanofabrication Facility is focused on the design, manufacturing and testing of Micro-Electrical-Mechanical Systems (MEMS). The collaboration of the Facility with the Consortium (Fig. 1) is focused on the manufacturing and testing of MEMS for different types of endoscopes for OCT.

In terms of teaching, the main interests of the Facility head, Prof. Ioana Voiculescu are to teach the students at UG and PG about emerging technologies. The emergence of new technologies that are revolutionizing the practice of engineering, the miniaturization of mechanical device, the advent of nanotechnology, the emergence of intelligent systems, the introduction of new and advanced materials, the development of sophisticated software and finally the revolution in biology are the base for modeling a modern curriculum in the Mechanical Engineering studies [79]. Based on these considerations the teaching is focused on the study of MEMS technology with a focus on optics applications. For the study of MEMS device a special commercial chip named Class on Chip (Class on a Chip, Inc., TX, USA) [80] is used. This chip is based on MEMS devices and provides innovative educational and research platforms for students at UG and PG level. This silicon chip has the dimensions 6.3 mm x 2.8 mm and contains 16 devices that move, allowing a wide range of experiments to be conducted. Several devices contain micromirrors (Fig. 4d). In the application from Fig. 4a-c the students learn the process to fabricate micromirrors; they can also analyze with the microscope the micromirror and the mechanical system used to actuate the micromirror. After the students are familiar with the concept of micromirror they are asked to find papers related to this topic and each student will have a short presentation of the paper selected by the student on micro-mirrors fabrication process and applications.

The applications in the industrial sector are increasing. There are several possible applications for MEMS and Nanotechnology in various fields like biotechnology (ex: biochips for detection of hazardous chemical and biological agents), medicine (MEMS pressure sensors) or communication (circuit) [81]. MEMS have a lot of advantages: small size and small scale allow to place a lot of different devices on the same system; it is also less expensive because we minimize the materials consumption used to make MEMS. With this kind of system you can transfer a small motion on nano-scale to a bigger motion on the macro-scale.

(f) **Arad County Emergency University Hospital** applies the OCT systems at the partners in conjunction with the handheld and endoscope scanning probes that we are developing in the project. Thus, the Department of Gastroenterology is using the equipments in gastroenterology and in colonoscopy - with endoscopic investigations. The Department of Pathological Anatomy performs the necessary histological analysis to provide the calibration of the technique and the necessary feed-back for validation of the OCT results.

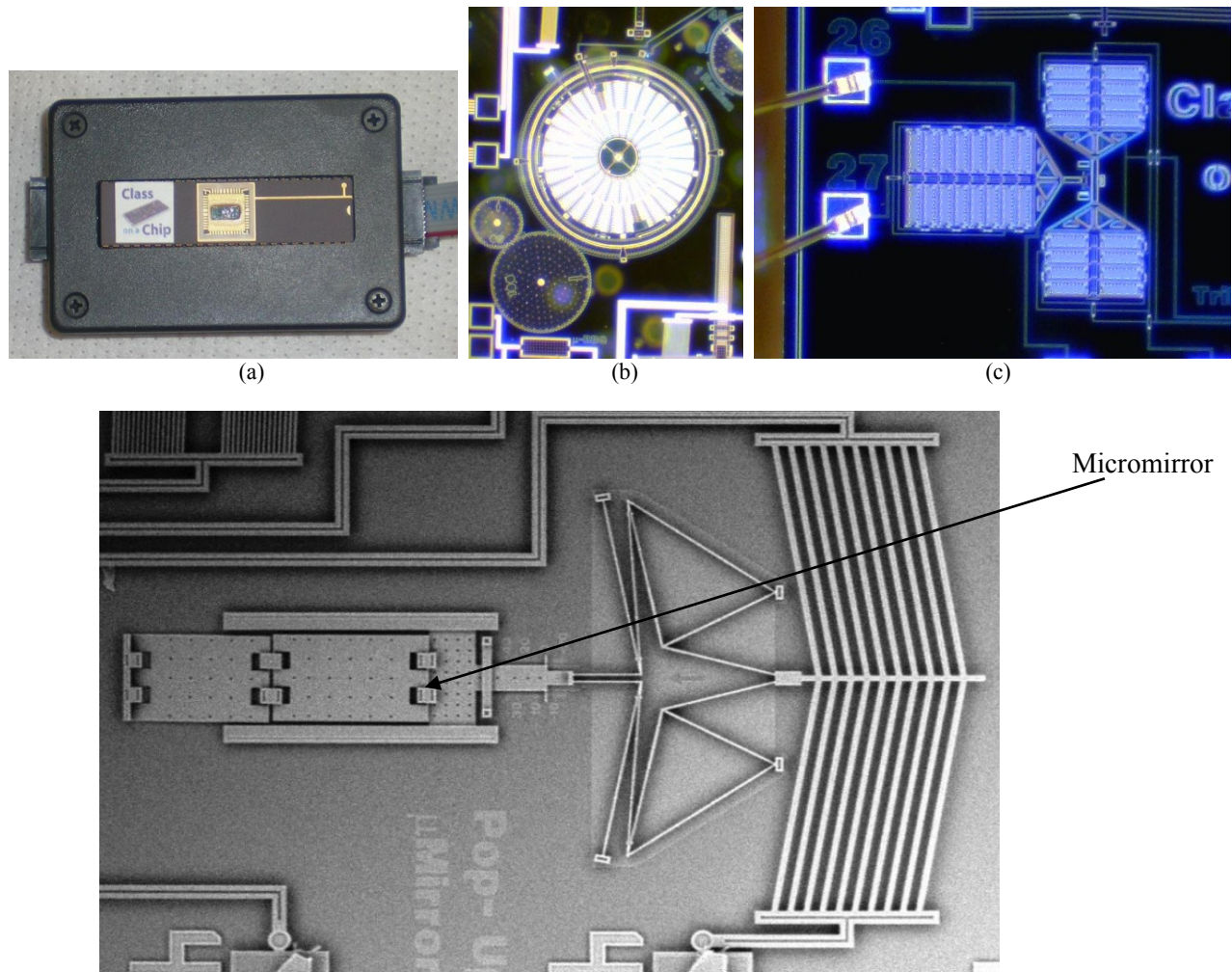


Figure 4. Lab-on-a-chip [65] used for MEMS teaching at the City University of New York (CUNY), NY, USA: (a) view of the chip mounted; (b) micro-motor and gears within the chip; (c) comb-drivers; (d) Micromirror MEMS structure on chip for student education with microstructures for optical applications.

The investigation itinerary is the normal one, as biological samples are first studied *in vitro*, and after the calibration, *in vivo*. We expect that at the end of the project the OCT equipments (system & different scanning probes) will be ready to move from lab to the clinic environment. Among the research objectives targeted there are: Barrett's esophagus and the investigation or the removal (endoscopically) of polypoid lesions. One has to stress that traditional procedures such as Ultra-magnifying Endocytoscopy, Autofluorescence Imaging, Chromoendoscopy or Confocal Laser Endomicroscopy have important advantages: they reduce unnecessary biopsies or resections, and they therefore decrease the risk of endoscopic complications. Their drawbacks (high costs, labor intensive, time consuming, and need experienced MDs) imposes OCT as a valuable tool for investigations. OCT will be used to differentiate between neoplastic and non-neoplastic lesions, and to increase the accuracy of the differential diagnosis, as in colon adenoma.

- (g) **S.C. Inteliform S.R.L. Timisoara** is a dynamic SME focused on Mechanical Engineering and Mechatronics, but also on Optical Engineering and Optomechanics. With 60+ employees, from which 16 are engineers, it was and is involved in several R&D projects. Its main activity is in the design, simulations and manufacturing of very diverse pieces and systems. In the Consortium it achieves the technology and manufacturing of prototypes. It also provides – at least in part - the technological transfer of the results obtained through research.

5. CONCLUSIONS

The paper presents our Consortium, our main collaborators [1, 2], our current Partnership Project [4] and some of its challenges. A few aspects related to the necessary interactions between universities and industry in our Consortium (and to the role of the later) were also pointed out. These efforts are part of a longer term strategy that aims to create the structure of a future Photonics pole in Western Romania.

Issues and activities related to the training of postgraduate (PG) students and to the teaching of undergraduate (UG) students (and to the translation of the research experience for the teaching process) are pointed out – at the academic partners. This paper completes – in terms of a collaborative structure – the presentation made on these aspects in [6] for the activity of the 3OM Optomechatronics Group [3].

Future work comprises further translation of the research results and expertise into the UG and Master curricula, the enhancement of our early research experience with UGs, and a better training of the PG, especially at Doctoral and PostDoc level, with a focus on driving them towards higher impact research - and publications - at an as-early-as-possible stage of their work.

Directions of development of the Photonics Pole structure are also envisaged, with the inclusion of other partners from the region and with the enhancement of the collaborations with our partners from Europe and USA. There is also a continuous, natural effort to attract significant funding for the development of our activities in R&D and to its applications in industry and medicine.

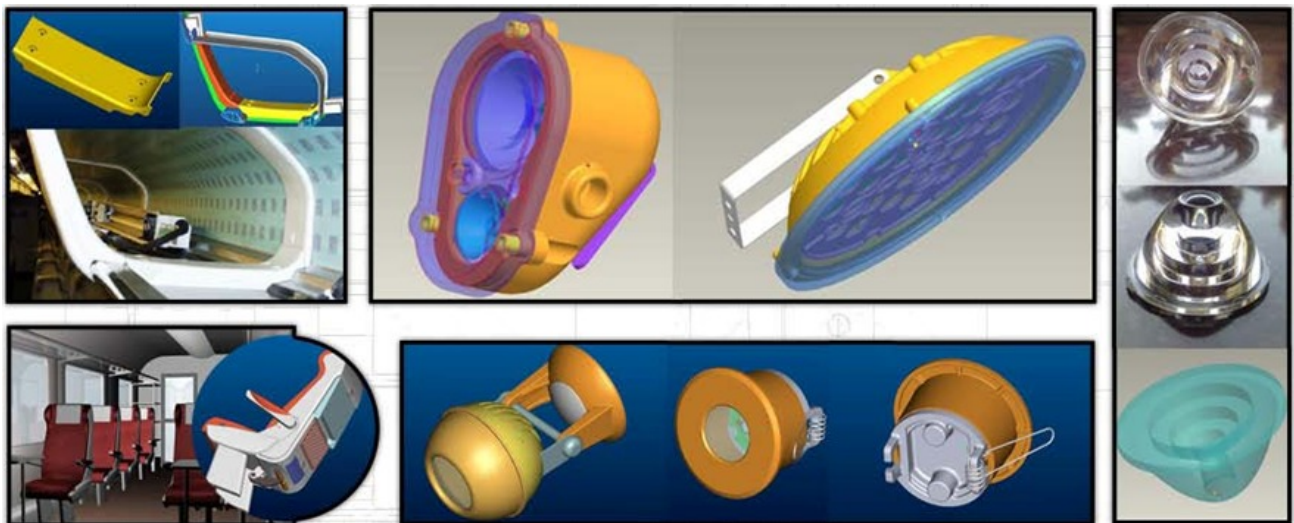


Figure 5. S.C. Inteliform S.R.L. Timisoara – examples of plastic molded parts (including optical) designed and fabricated.

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