Il Colle di Galileo

Vasco Ronchi Colloquia: vision on Technology Transfer

Arcetri, April 3, 2023

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Abstract. The National Institute of Optics has launched an event format for the dissemination of research results aimed at an entrepreneurial audience: the Vasco Ronchi Colloquia (VRC). The VRCs are focused on research results suitable for a technology transfer path and have been named in memory of the illustrious founder of the Institute, physicist Vasco Ronchi. This report presents the formula devised for the VRCs and an in-depth analysis of the topics covered by the first VR Colloquium, held on April 3rd 2023 at the Arcetri headquarters of the CNR-INO.

Keywords. Vasco Ronchi, Technology Transfer, Optics.

Context

The transformation of research results into new technologies and, ultimately, novel industrial processes and products is the cornerstone of innovation. This transfer can only be achieved by disseminating research results to companies, raising awareness in researchers of the technological needs of industries, informing investors about novel prospects and ultimately involving all the potential actors in the innovation process. Thus, the need to create a series of events where researchers, companies and investors could sit down together, sharing experiences and discussing opportunities.

The National Institute of Optics was founded in 1927 by Vasco Ronchi (Figure 1) to achieve national independence in the development and realization of optical components and instruments. This was a remarkably modern idea, fulfilling a need that, one hundred years later, has only grown stronger. It was, therefore, only natural to dedicate this new format of events to the Institute's founder, establishing the *Vasco Ronchi Colloquia*.

True to the tradition of the Institute as a research center, the format of the VRC was conceived like an experiment: 1) state the applications to be highlighted; 2) formulate a model; 3) design and imagine the experiment; 4) perform the experiment; 5) review the data.

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1) State the application to be highlighted:
   For the first installment of the VRC, we chose the general topic *Optics for everyday life*, selecting novelties in the fields of diagnosis and treatment of visual disorders, optical wireless communication, optical imaging for search and rescue in fires, optical techniques for surgical guidance and novel perspectives offered in theragnosis by strong laser pulses.
2) Formulate a model:
   The VRC are to be structured with:
   a. An introduction on opportunities and synergies with ongoing Technology Transfer (TT) initiatives.
   b. A tutorial by a TT expert.
   c. An example of a successful case of technology transfer.
   d. 4/5 market-attractive technologies to be presented to a select corporate target audience.
   e. Face-to-face dialogue between researchers and companies on technologies of interest.
3) Design the experiment:
   a. As an Introduction, an overview of the possible collaboration between INO and companies, both in general and in relation to current funding opportunities for companies and a landscape of CNR-INO synergies with ongoing TT initiatives.
   b. As a Tutorial, a brief overview of the TT path and its key points and common problems, or insights into specific aspects, such as the approach to patenting or licensing, can represent extremely interesting interventions for both researchers and entrepreneurs.
   c. As a successful case, present a start-up created in recent years by CNR researchers who can share their positive TT experience.
   d. A selection of technologies suitable for the market proposed with attractive wording for companies. This envisaged a first phase of scouting the research results among researchers to identify technologies that have strong potential for applications to be transferred to the market. In a subsequent phase, the researchers involved were invited to illustrate their technology through some key points "speaking" to the companies: an explanatory ***title*** and a ***subtitle*** explaining the possible use of the technology proposed; the ***value proposition*** that takes into account the potential competitive advantage compared to what the market offers; the ***key technologies*** underlying the research results; ***applications*** that can benefit from the technology; the scientific ***background***, including references to Intellectual Property (patents, articles, projects).
   e. An interactive session between researchers and companies during informal refreshments.
4) Perform the experiment:
   The 1st successful *Vasco Ronchi Colloquium* was held in Arcetri on April 3rd 2023,

with the title "Vision on Technology Transfer". The event was organized by CNR-INO together with the European Laboratory for Non Linear Spectroscopies (LENS), as part of the initiatives promoted in the Artes4.0 Competence Center.

a. The introductory talk was given by the director of CNR-INO, Francesco Saverio Cataliotti, on *Opportunities and collaboration tools with companies* (Figure 2): highlighting collaboration instruments between CNR institutes and enterprises, which range from contracts for third parties to agreements for fund driven research activities, industrial PhDs and joint research laboratories. Furthermore, CNR Institutes can sign co-financing agreements for innovation projects with companies. Tuscan CNR Institutes are associated within the newly born **Centratech**, a TT "incubator" located in the CNR Research Area of Sesto Fiorentino. Other examples of current opportunities where INO is already involved are, at national level, the **Artes4.0 Competence Center**[1] and **PRISMA**[2] project, and **PhotonHub Europe**[3] project at international level.
b. Technology Transfer expert Massimo Gentili was invited to give the talk "*From Research and Development to Research for Innovation*": a comprehensive overview to translate a research idea into a commercial device explaining the risk of the "Valley of Death" of innovation, investors' needs from research teams, which are the strategies for promoting the research idea, etc… that investors would expect, what would come next in terms of innovation, what would be the vision of an "outsider", a newcomer to optic science.
c. *The successful case* chosen for the first VRC was the Regensight start-up: *Biophotonics for personalized treatment of visual disorders: the Regensight case study.*
d. The first four technologies selected and presented at VRC, explained in detail in this article, are:
   1st Technology - Visible light communication for wireless data transfer
   2nd Technology - IR Digital Holography for the detection of building oscillation modes
   3rd Technology - Plus Tip: an optical solution for surgical guidance
   4th Technology - NIR Ceramic laser amplifier to enhance manufacturing processes and develop innovative theranostic approaches.
e. Half an hour's interaction within a *Coffee time between entrepreneurs and innovators: in-depth study with researchers on the technologies of interest*. Furthermore, to support the dialogue between researchers and entrepreneurs, "technological leaflets" summarizing all the key points previously identified were distributed. These leaflets were designed in A4 format, with the ***title***, ***subtitle*** and reference contacts, together with an evocative image of the technology, on the front, and the ***value proposition***, ***key technologies*** used, possible ***applications*** and related ***background*** on the back[4].

5) Review the data: After the event, a follow-up e-mail was sent to all participants with a link to the technological datasheets presented during the *Colloquium*, to offer a targeted and widespread action and to encourage the participating

Figure 1. The Italian physicist Vasco Ronchi (Florence, December 19, 1897 – Florence, October 31, 1988).

Figure 2. Institutional Welcome from Francesco S. Cataliotti, Director of CNR-INO and Elisabetta Cerbai, Director of LENS and Introductory Talk on Opportunities for TT.

companies to ask for support to overcome possible weaknesses or to achieve specific goals. We are currently setting up one-to-one meetings between industries and researchers.

Topics

The successful case – Biophotonics for personalized treatment of visual disorders: the Regensight case study
By Giuseppe Lombardo

Regensight, an Italian start-up company based in Rome. It has developed a breakthrough platform based upon theranostic technology for correcting major visual disorders at all ages and is clinically validating it. Theranostics is a breakthrough medical solution based on **the**rapy guided by imaging dia**gnostics** for providing tailored therapies. The Regensight platform improves vision by inducing the controlled photo-polymerization process of corneal tissue proteins through UV-A light mediated delivery and photo-activation of a bio-chromophore in the cornea.

Context: Refractive ocular disorders affect more than **2/3 of the world's population** and require some type of optical correction to perform normal daily activities. Currently, **surgical treatments of visual disability are invasive and associated with known problems**, such as pain and risk of severe complications (e.g., infection, corneal scarring, corneal ectasia), **which may result in the loss of vision**. These issues greatly limit the widespread adoption of current surgical treatments, which have a penetration rate among the candidate population (young people with natural myopia and elder people with residual myopia after cataract surgery) of less than 1%. In addition, there is **no effective and safe surgical solution for** the most frequent and demanding visual disorders, such as **presbyopia**, which affect more than 40% of people worldwide.

Value proposition: create and **validate a minimally invasive surgical correction of visual disorders based on theranostics**, elevating the current therapeutic standard for improving sight in:

- ***keratoconus*** *(2% prevalence), which is the primary cause of corneal transplant in young adults;*
- ***low-grade myopia*** *(>9% prevalence), which is the primary cause of visual disability in young adults;*
- ***presbyopia*** *(>40% prevalence), which represents the primary cause of visual disability in the elderly.*

Visual correction is attained through the precise and personalized **remodelling of the biomechanical properties of the cornea induced by theranostics-guided photo-polymerization of stromal proteins with UV-A light and riboflavin**.

The Regensight platform consists mainly of:

- a mechatronic system for precisely focusing the UV-A light onto the cornea;
- a theranostic system for real time measurement of the corneal concentration and distribution of riboflavin and its photo-activation in the cornea;

– a corneal topography system for measuring the corneal curvature;
– an artificial intelligence algorithm for system improvement with clinical use;
– an IoMT system for remote and predictive maintenance of the platform;
– a riboflavin ophthalmic solution for human use.
– a corneal iontophoresis delivery device for controlled application of riboflavin on the cornea via connection with the theranostic platform.

How does the platform work: Rengensight has incorporated theranostics technology into a UV-A medical device, C4V-CHROMO4VIS© (Figure 3A), for targeting the precise therapeutical dose of riboflavin and UV-A light energy with a view to improving corneal cross-linking outcome predictability and eliminating the risks of adverse events. Thanks to **real-time monitoring of the corneal concentration of riboflavin** (Figure 3C), this novel approach can make transepithelial treatment protocols confidently effective in treating patients. Pre-clinical studies [1][2][3][4][5] have provided enough evidence on the accuracy and precision of the theranostic UV-A medical device for inducing **highly predictable tissue stiffening** in human donor corneal tissues. The novel UV-A device has emerged as a promising and powerful tool to precisely monitor the diffusion of riboflavin

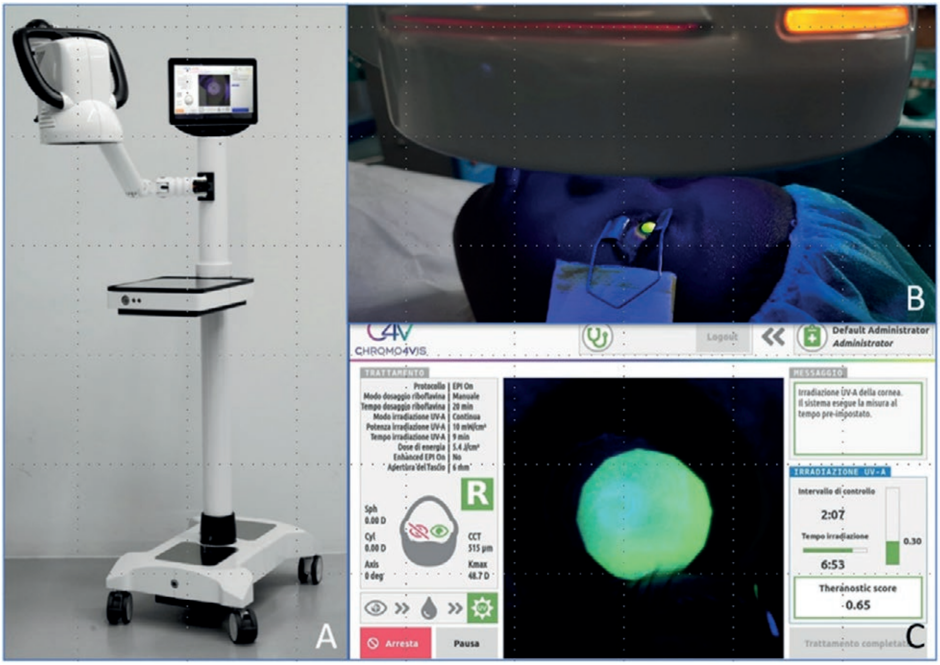

Figure 3. A. C4V CHROMO4VIS medicalã device. B. A patient, recruited in the multicentre clinical trial, during an Epi-ON theranostic-guided CXL procedure. C. During theranostic-guided UV-A irradiation of the cornea enriched with riboflavin, the C4V CHROMO4VIS © calculates the theranostic score estimating treatment efficiency.

into the corneal stroma and its UV-A light mediated photo-degradation during treatment. In addition, it has the ability to estimate CXL treatment efficacy, providing an imaging biomarker, i.e., the theranostic score, which correlates with the treatment-induced stromal stiffening effect.

A **randomized multicentre clinical trial** entitled "**A**ssessment of the**r**anostic **g**uided rib**o**flavin/UV-A corneal cross-linking for treatment of keratoconus" (https://clinicaltrials.gov/ct2/show/NCT05457647) is confirming the predictive ability of the theranostic score in assessing the clinical efficacy of the corneal cross-linking procedure for the treatment of keratoconus [6] (Figure 3B).

From the idea to the patient: The co-founders of Regensight are **Marco** and **Giuseppe Lombardo**, two brothers who began working together more than 15 years ago, their mission being to create smart, safe and effective solutions for preventing and treating major eye disorders. Marco is an **eye doctor and holds a PhD in Biomedical engineering and Computer Science**; he is an expert in regulatory strategy, subsidiary finance and has strong technical competence in medical device and pharma product development and clinical trial design. Giuseppe is senior **biomedical engineer** researcher at CNR (National Research Council in Italy) **and holds a PhD in Electronic Engineering**; he is an expert in the biophotonics field and in technology transfer. Marco and Giuseppe have created a multidisciplinary team of experts for investigating, modelling and characterizing the optical and biomechanical properties of corneal tissue; these studies allow the brothers to understand the main principles of interaction between riboflavin and UV-A light and their mechanism of action in the cornea of the human eye.

Immediately after validation of the proof-of-concept in the lab, Marco and Giuseppe submitted a first family patent application (through the parent company Vision Engineering Italy srl). Then the Lombardo brothers set out on their own path to promote and transfer their idea from the bench to the patient – crossing the well-known valley of death between research and the commercialization of technology. The brothers developed another prototype in order to promote their idea, participating in National and International competitions, and also submitted second and third family patent applications. Several Italian venture capitals and business angels knocked at their door, with real or fake interest, but the brothers chose to go ahead on their own, as the investors did not share their aim of transforming current methods of vision correction. This led to the brothers' decision to fund Regensight, which would be responsible for leverage the novel technology for treating visual disorders created by the parent company Vision Engineering Italy srl, which took care of investment for pre-competitive development. During the development of the theranostic medical device, new shareholders entered the company, bringing skills and competence in **medical technology, strategic marketing** and **pharma business development**. The company raised funds also by winning national public grants which where fundamental to achieving its goal of developing the platform. The start-up has **raised € 1,600,000** to date and has been **granted € 100,000** by Public Competitive Grants.

Thanks to the pre-competitive work carried out by Marco and Giuseppe in Vision Engineering Italy before founding the start-up, **in less than two years**, from July 2019 to May 2021, Regensight achieved **ISO 13485:2016 quality management system certification** for developing and manufacturing active medical devices and **two CE certified medical devices** ("C4V CHROMO4VIS" and "RitSight"), the first two modules of the theranostic platform.

[1] Lombardo G et al. Non-invasive optical method for real-time assessment of intracorneal riboflavin concentration and efficacy of corneal cross-linking. J Biophotonics 2018;11(7):e201800028.
[2] Lombardo M, Lombardo G. Non-invasive and real time assessment of riboflavin consumption in standard and accelerated corneal cross-linking. J Cataract Refract Surg 2019; 45:80-86.
[3] Lombardo G et al. Comparison between standard and transepithelial corneal cross-linking using a theranostic UV-A device. Graefes Arch Clin Exp Ophthalmol 2020; 258(4):829-834.
[4] Lombardo G et al. Theranostic-guided corneal cross-linking: pre-clinical evidence on a new treatment paradigm for keratoconus. J Biophotonics 2022; Dec;15(12):e202200218.
[5] Lombardo M et al. Predicting corneal cross-linking treatment efficacy with real-time assessment of corneal riboflavin concentration. J Cataract Refract Surg. 49, 635 -641(2023).
[6] Roszkowska AM et al. A randomized clinical trial assessing theranostic-guided corneal cross-linking for treating keratoconus: the ARGO protocol. Int Ophthalmol 43, 2315 – 2328 (2023)

1st Technology – Wireless communications through light: a pervasiVisible Light Communication (VLC) – data transfer through light

By Jacopo Catani

The innovative wireless communication technology **VLC** (**Visible Light Communication**) aims at casting wireless data over the air by modulating the intensity of the light emitted by common LED sources, without perception by the human eye. This technology, which is at the basis of the "optical evolution" of Wi-Fi, known as Li-Fi, uses LED lamps to provide simultaneous illumination and communication. By leveraging the optical nature of the carrier, VLC can attain very low latencies, even lower than a millisecond, and virtually, bandwidths exceeding the Gbps. Furthermore, its pervasive nature can enable advanced communication protocols which are the core of the Internet of things (IoT) approach,

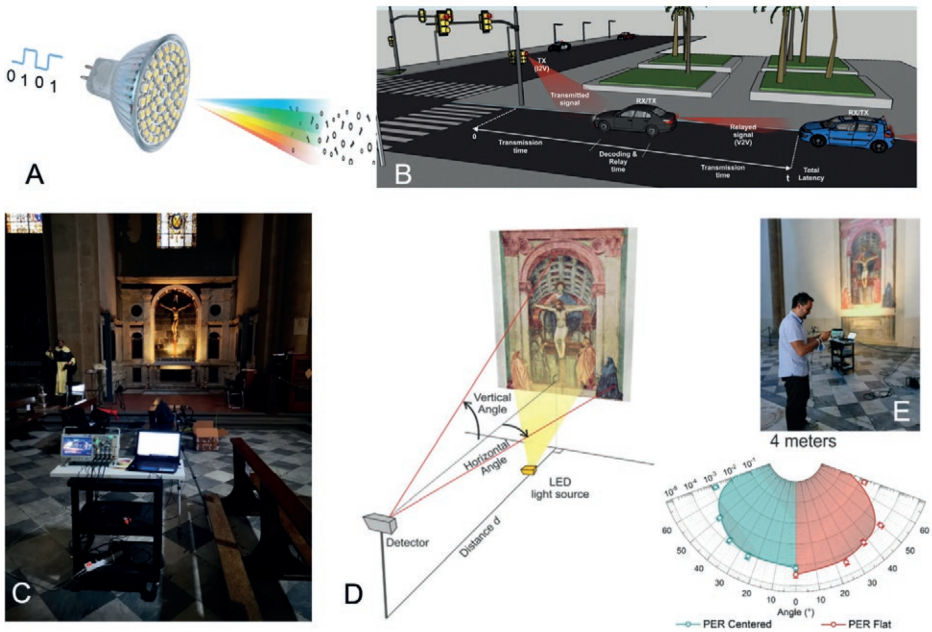

Figure 4. A – LED light source. B – Active decode and relay (ADR) transmission chain based on VLC for Intelligent Transportation Systems. Data are cast by the traffic light LED lamp to an incoming vehicle (black), which can receive, decode and relay information to a trailing vehicle (blue) via taillights. Observed latencies approach 0.5 ms at a rate of 240 kbaud [7]. C, D, E – Example of VLC system tested in a real museum scenario, in the Basilica of Santa Maria Novella in Florence [8]. Digital data are transmitted to visitors exploiting the same light used to illuminate artworks (NOTE: All of the artworks shown or represented here are the property of Fondo Edifici di Culto, Ministero dell'Interno – Italy).

making VLC one of the key assets for the 6th generation wireless communication architecture (6G).

In this scenario, we have developed and tested **several implementations of innovative VLC links**, in indoor and outdoor applications. More specifically, we would like to report two use cases (Figure 4).

The first case involves the realization of a VLC link in a real **museum**. In particular, we implemented a thorough campaign in the world-famous basilica of Santa Maria Novella in Florence to assess and demonstrate the possibility of transmitting digital information to visitors exploiting the existing LED-based infrastructure used to illuminate artworks. This has noticeable implications for visitors in terms of **dedicated services**, **indoor positioning**, **augmented reality** and **enhanced content fruition**, not only in the museum setting, but also in **public, industrial** and **retail** sectors.

We tested the VLC performances, using a prototype developed in our labs, on both artworks (frescoes, wood paints and canvas) and sculptures. LED lamps illuminating the artworks were enabled for VLC by specific modification of the current driver, to inject data on the optical carrier as intensity modulation. We can measure the quality of the VLC link by measuring the ratio of bad to good packets received (packet error rate – PER), for realistic positions and distances of a visitor moving nearby a specific artwork. We found satisfactory VLC transmission for distances up to 4 m and angular ranges of more than 80°, demonstrating that, by properly tuning the field of view (FoV) of the receiving stage (RX), contiguous VLC hotspots (one per artwork) could be distinguished, so that each lamp could cast specific information on each artwork or illuminated object.

The second case we would like to report is related to the exploitation of VLC for **Intelligent Transportation Systems** (ITS) in **vehicular applications**. On this topic we also filed a **Patent** procedure describing an advanced anti-collision system based on VLC for vehicles approaching road intersections (PCT/EP2021/069200 2021 – Euro-PCT in EUROPE No. 21743429.9).

In our work, we demonstrated the potential for digital transmission from a traffic light to approaching vehicles through the traffic light LED lamps. The data transmitted can be received, decoded and relayed to a further incoming vehicle in **less than 1ms**, leveraging the possibilities offered by the optical carrier used in VLC. This reduced latency value has a profound impact on the nature of safety protocols which can be implemented, aimed at avoiding traffic jams for example, as well as vehicle platooning, traffic optimization and avoiding collisions, with enhanced performances with ADAS 2 autonomous driving levels, towards implementations of level 4 and 5 which are still largely unexploited. For example, we could demonstrate that the stop distances at 90 km/h can be reduced from 80 m (human reaction time) to less than 50 m by employing VLC to trigger an automated braking reaction in the event of a sudden insurgence of critical events such as another vehicle thoughtlessly entering the crossing area ignoring a red light.

[7] T. Nawaz, M. Seminara, S. Caputo, L. Mucchi, F. S. Cataliotti and J. Catani, “IEEE 802.15.7-Compliant Ultra-Low Latency Relaying VLC System for Safety-Critical ITS,” in *IEEE Transactions on Vehicular Technology*, vol. 68, no. 12, pp. 12040-12051, Dec. 2019, doi: 10.1109/TVT.2019.2948041

[8] M. Seminara, M. Meucci, F. Tarani, C. Riminesi and J. Catani, “Characterization of a VLC system in real museum scenario using diffusive LED lighting of artworks” Photon. Res. 9, 548-557 (2021)

2nd Technology -Infrared Digital Holography: imaging through smoke and flames

By Massimiliano Locatelli

Digital Holography (DH) is an interferometric imaging technique which allows the recording and, subsequently, reconstruction of the amplitude and phase information of the wave front coming from an object irradiated with coherent radiation. Due to its versatility, DH has been successfully used in various fields of application such as microscopy, metrology, industrial inspection, 3D vision, etc.

The transition from visible radiation toward longer IR wavelengths, in DH, guarantees a wider field of view and a relatively lower sensitivity to vibration which, combined with the peculiar properties of the various windows in the IR range, pave the way for numerous further relevant applications. One of the most promising of these applications is “Vision through smoke and flames”, first demonstrated in 2013 [9] at CNR-INO in the Long Wave IR (LWIR) range, using CO_2 laser radiation at 10.6μm. In fact, unlike ordinary visible light imaging systems (which cannot see through thick smoke) and unlike conventional thermal imaging techniques (which can see through smoke but are blinded by flames), Infrared Digital Holography allows vision even through an impenetrable curtain of smoke and flames. Vision through smoke is achieved due to the well-known ability of IR radiation to penetrate almost undisturbed through various scattering media in the visible range, like smoke. Vision through flames, on the other hand, is a specific peculiarity of holography, made possible by two different characteristics of this technique: first, since the radiation emitted by the flame is not coherent with laser radiation, it does not contribute to the interferometric pattern which contains all the information on the scene investigated; secondly, holography is a lensless imaging technique, so no image of the flame is focused on the detector surface and any saturation effect is avoided (Figure 5).

Obviously, this result has significant application potential in the field of fire emergency where it could allow rescuers (firefighters, civil protection, etc.) to move safely in scenarios invaded by smoke and flames, helping them identify people/things to be saved. Currently, the technique has been revised using Short Wave IR radiation at 1.55 μm. These wavelengths, widely used in the communications field, offer various advantages. First of all, these wavelengths are considered relatively safe for the eyes. Secondly, compact and robust fiber coupled lasers are available and this means being able to decouple the source from the interferometric system so that the source, which has smaller dimensions than CO_2 lasers, can be carried separately in a backpack while the optical interferometric system can be miniaturized and incorporated into the equipment, by mounting it on a

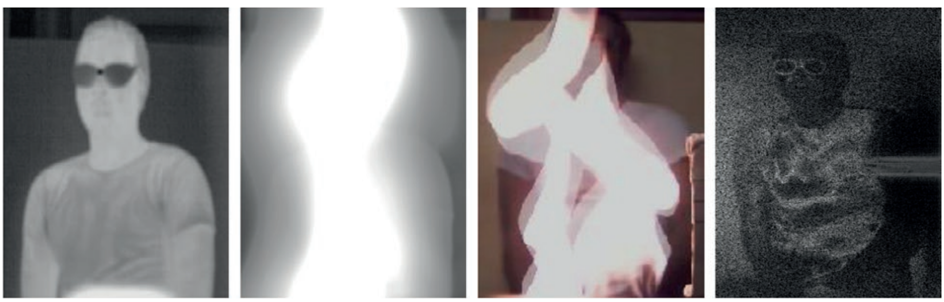

Figure 5. Imaging of a human being seen through stove flames. From left to right, thermographic image without flames, thermographic image with flames, visible image with flames, holographic amplitude image with flames.

rescuer's helmet for example or carrying it by hand like a flashlight. Furthermore, sensors in the SWIR region, such as InGaAs detectors, are highly efficient and this allows the reduction of laser power sent to the investigation scene. Finally, the possibility of reducing the exposure time of the detector down to a few tens of microseconds allows the interferometric fringes to be frozen and, ultimately, allows the system to be portable, despite it being highly sensitive to the vibration interferometric system. The device currently developed at CNR-INO works with a 1W laser source and is able to visualize a 1m diameter scene hidden by smoke and flames within a radius of about 10m. The device in the LWIR region is patented [10] while an Italian patent application has been recently filed for the portable device in the SWIR range [11].

[9] M. Locatelli, E. Pugliese, M. Paturzo, V. Bianco, A. Finizio, A. Pelagotti, P. Poggi, L. Miccio, R. Meucci, P. Ferraro. Imaging live humans through smoke and flames using far-infrared digital holography. Optics Express 21 (5) pp 5379–5390 (2013) http://dx.doi.org/10.1364/OE.21.005379.
[10] Patent US 9310767 B2.
[11] Italian patent application n. 812023000061572.

3rd Technology -Time-gated imaging probe (+TIP)
By Riccardo Cicchi

Our Time-gated imaging probe (+TIP) offers an optical solution to perform real-time tissue assessment without biopsy in a clinical/surgical scenario. The proposed solution is based on measuring tissue autofluorescence lifetime using a Time-Correlated Single Photon Counting (TCPSC) approach and on real-time data processing for augmented-reality visualization [12] [13] [14].

Autofluorescence measurements are particularly attractive for clinical research, as they exploit the photo-physical properties of endogenous molecules to provide label-free contrast and report structural and functional properties of biological tissues, without the use of potentially toxic exogenous contrast agents. Consequently a detailed structural, metabolic and molecular characterization of the tissue under investigation is provided (Figure 6 a), b) and c)).

The information provided by the approach proposed is extremely useful in a clinical scenario as it can be used to: i) facilitate the early diagnosis of a lesion without any tissue biopsy; ii) outline tumor resection margins; iii) monitor the response to a specific therapy; iv) predict outcomes and improve prognostic accuracy. To be precise, the approach proposed permits the rapid identification and characterization of tissues from structural, metabolic and molecular perspectives, adding both sensitivity and specificity to the clinical examination. In addition, autofluorescence lifetime measurements can provide guidance for the surgeon,

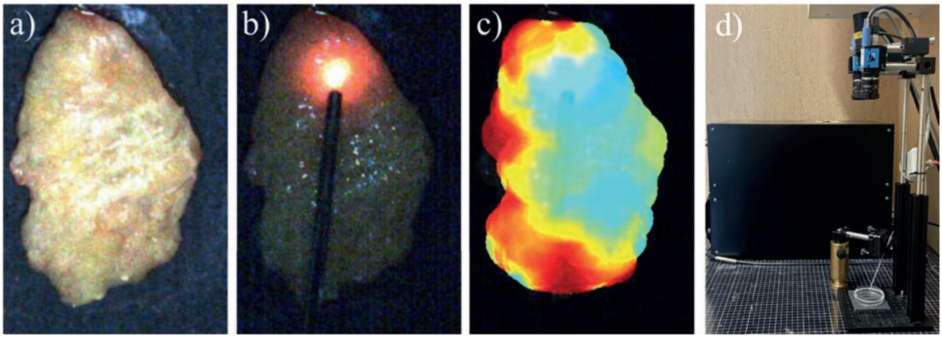

Figure 6. An example of the structural, metabolic and molecular information provided by +TIP technology during the examination of a tissue biopsy of pancreatic cancer (a), shown together with the fiber probe during acquisition (b) and represented as augmented reality on a color-coded scale (c). (d) shows the lab prototype developed and now in use for measurements on liver, colon and pancreatic cancer specimens.

reducing the number of unnecessary biopsies. +TIP technology could also play a key role in follow-up therapy through surveillance targeting the early detection of recurrence through the identification of accurate predictors of pathological response, thanks to the *in situ* structural, metabolic, morphological and molecular assessment of cells and tissues.

The technology proposed offers significant advantages over the current state-of-the-art and standard clinical methods. First, the technique based on autofluorescence lifetime is label-free and does not require the administration of exogenous contrast agents. A major limitation of TCSPC is its inability to distinguish fluorescence photons from background photons, e.g. from ambient room light or direct bright-field illumination, which makes TCSPC measurements impractical under bright background light conditions. In our solution, fluorescence and background photons can be temporally separated in order to guarantee both sample illumination and a background-free fluorescence signal. Furthermore, data processing takes place in real-time and the results can be displayed as augmented-reality in digital devices. In short, the technology proposed allows the acquisition of the autofluorescence signals emitted by endogenous fluorophores under bright background conditions and representing the structural, metabolic and molecular information as augmented reality in digital devices after real-time data processing. This provides an immediate advantage for the deployment of the technology in a surgical scenario, as the surgeon has immediate access to structural, metabolic and molecular information using a method compatible with many clinical procedures.

Currently, a lab prototype (Figure 6 d)) has been developed and is undergoing testing on liver, colon and pancreatic cancer specimens in collaboration with the clinicians of the University of Florence. The maturity level of the technology proposed is now on a TRL4/5. A budget of about 350/400 keur is required for reaching a TRL7.

In conclusion, the method presented here will establish a new framework of research and innovation that can boost routine clinical deployment of TCSPC-based autofluorescence lifetime measurements.

[12] J.L. Lagarto, V. Shcheslavskyi, F.S. Pavone, and R. Cicchi, Real-time fiber-based fluorescence lifetime imaging with synchronous external illumination: A new path for clinical translation, J Biophoton 12, e201960119 (2019)
[13] J.L. Lagarto, V. Shcheslavskiy, F.S. Pavone, and R. Cicchi, Simultaneous fluorescence lifetime and Raman fiber-based mapping of tissues, Optics Letters 45, 2247-2250 (2020)
[14] J.L. Lagarto, F. Villa, S. Tisa, F. Zappa, V. Shcheslavskiy, F.S. Pavone, and R. Cicchi, Real-time multispectral fluorescence lifetime imaging using Single Photon Avalanche Diode arrays, Scientific Reports 10, 8116 (2020)

4th Technology -NIR Ceramic laser amplifier to enhance manufacturing processes and develop innovative theranostic approaches
By Leonida A. Gizzi

Recent advances in high power laser applications, like laser-plasma acceleration and related user-oriented, compact light sources, as well as laser-driven fusion, call for the development of a new generation of broadband and short pulse lasers with high average power and repetition rate. High peak and average power laser systems can be realized by exploiting the advantageous properties of thulium-doped laser active materials, characterized by a long energy storage lifetime of up to 15ms, broadband emission, and absorption spectrum that allows direct diode pumping instead of the old flashlamp pumping, and the possibility to use the multi-pulse extraction technique [15].

Our innovative thulium amplifier is designed for multi kW average power, pulse durations of less than 100 fs and pulse repetition frequency of 1 kHz. These characteristics make it an ideal tool for enhancing manufacturing processes, for the industrial treatment of materials and functionalization of surfaces. The biomedical field is undoubtedly the other main application of this class of amplifiers, for innovative theranostic approaches. More in detail, laser-driven acceleration of electrons with energy in the range ~100–250 MeV and repetition rates in the range ~0.1–1 kHz offers a very promising route to novel radiotherapy protocols, possibly taking advantage of the recently discovered FLASH effect that opens new perspectives for high precision tumor treatment and reduced side effects on surrounding healthy tissues. An experimental platform is available at INO for the development of this novel laser technology, to test the optical, thermal, mechanical modelling and application aspects related to laser-matter interaction, and therefore to the generation of plasmas and compact, high gradient particle acceleration.

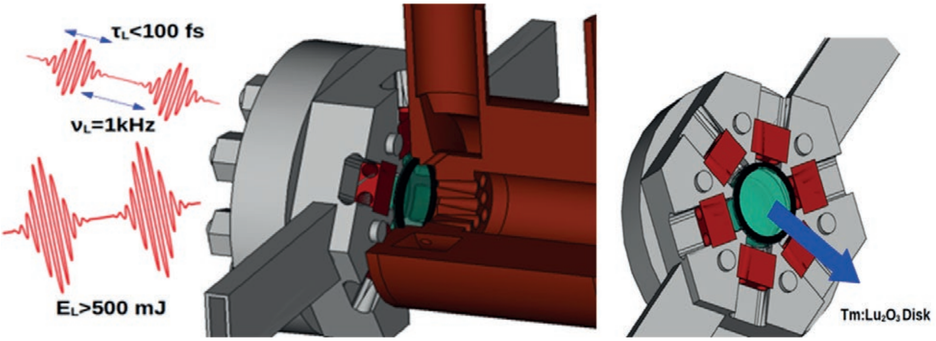

Figure 7. Cutaway scheme of the amplifier. The rear cooling is presented in copper. The jet-plate is placed just behind the disk. Fiber-holders are shown in red while the rectangular pipes represent the inlet and the outlet of the frontal cooling. On the right, the active-medium disk with a radius of 6 mm is shown in green. Pumping fiber holders, shown in red, are arranged in a hexagonal structure. A total of 12 fibers are used.

[15] Tamer et al., "1 GW peak power and 100 J pulsed operation of a diode-pumped Tm:YLF laser," Opt. Express 30, 46336-46343 (2022).
[16] D. Palla et al., "A model for pumping optimization in edge-pumped disk amplifiers", Optics & Laser Technology, 156, 108524 (2022).

Final Remarks

The event was disseminated/advertised in the mailing list of the Competence Center Artes4.0 of which CNR and LENS are members, on social channels (such as LinkedIn) and to a target audience (specific industrial partners) identified by CNR-INO researchers. The result has been an event of particular resonance in terms of participants, most of whom online, with some in person. The decision to opt for a mixed event both online and face-to-face was taken to met the needs of companies with tight deadlines while guaranteeing effective, interactive and immersive actions. Each talk/pitch was followed by a question time. Last but not least, it was useful for sharing scientific enhancement between researchers working in different teams. So the event had two important outcomes, one external and one internal, confirming the importance of sharing knowledge at all levels.

The event generated interest in a fairly diverse audience comprising regional officials involved in technology transfer and innovation initiatives, large associations, such as sections of Confindustria, and companies in general with which the CNR-INO already had ongoing collaborations.

Lastly, we had the unique pleasure and opportunity of having Professor Lucia Ronchi Abbozzo, daughter of our founder, as a very special participant.

Given the success of the first VRC, we are looking forward to the organization of other events based on the model described in this paper, to present further technologies and research.

Notes

[1] Industry 4.0 Competence Center on Advanced Robotics and enabling digital Technologies & Systems, https://www.artes4.it/en/

[2] The PRISMA (Prato SMart Industrial Accelerator) Project is part of the funding granted by Ministry of Business and Made in Italy (MIMIT) in the context of the Emerging Technologies Houses, https://www.prismaprato.it/it/pagina1706.html

[3] https://www.photonhub.eu/

[4] https://www.ino.cnr.it/wp-content/uploads/2023/08/Schede-Tecnologiche_Vasco_Ronchi.pdf