



The Optics Lab at ICTP

Humberto Cabrera Morales

Winter College on Optics: Terahertz Optics and Photonics
February 2023



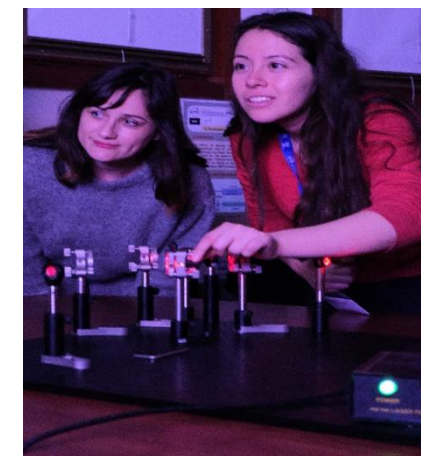
United Nations
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Optics Lab

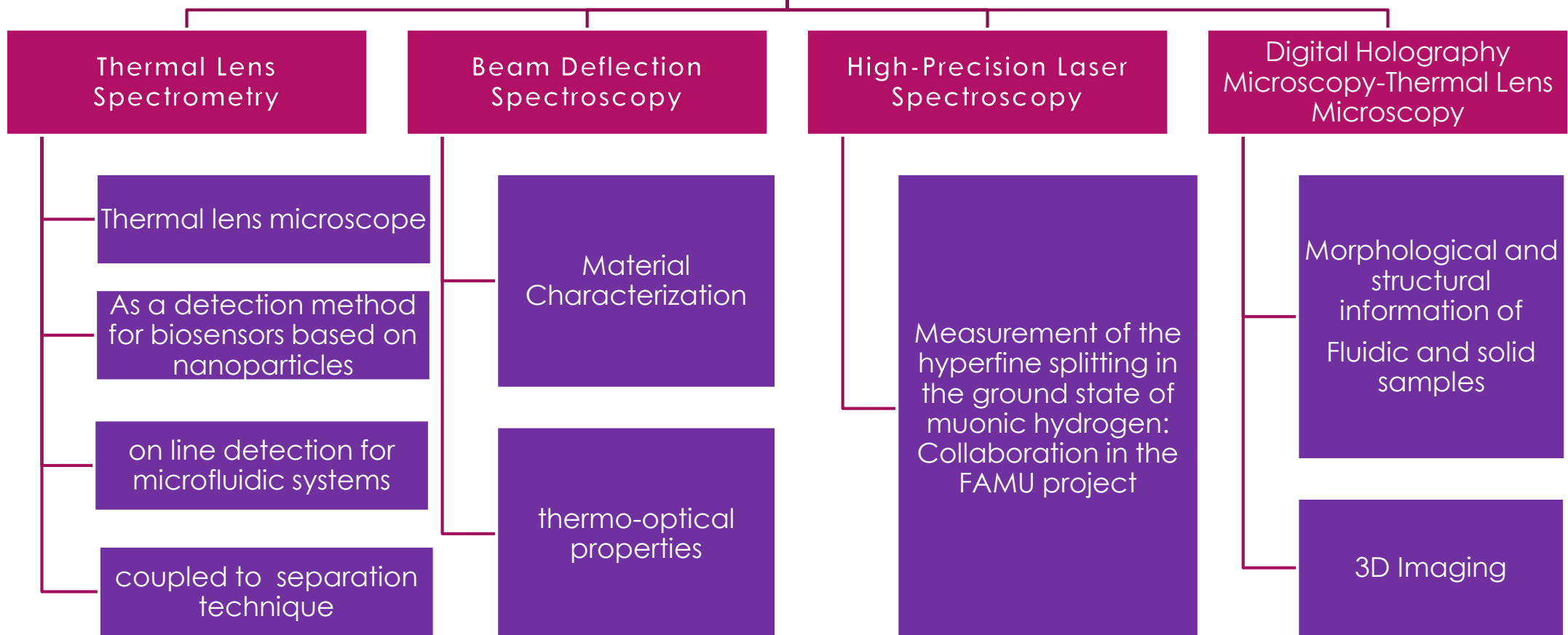
Early days (2015) of the modern ICTP Optics Lab on the ICTP campus combining training with research production and career development for young scientists from developing countries

Sustaining operation throughout the year as a productive research laboratory physically located *on the ICTP campus* was made possible by partnership with SPIE through the SPIE-ICTP Anchor Research Program

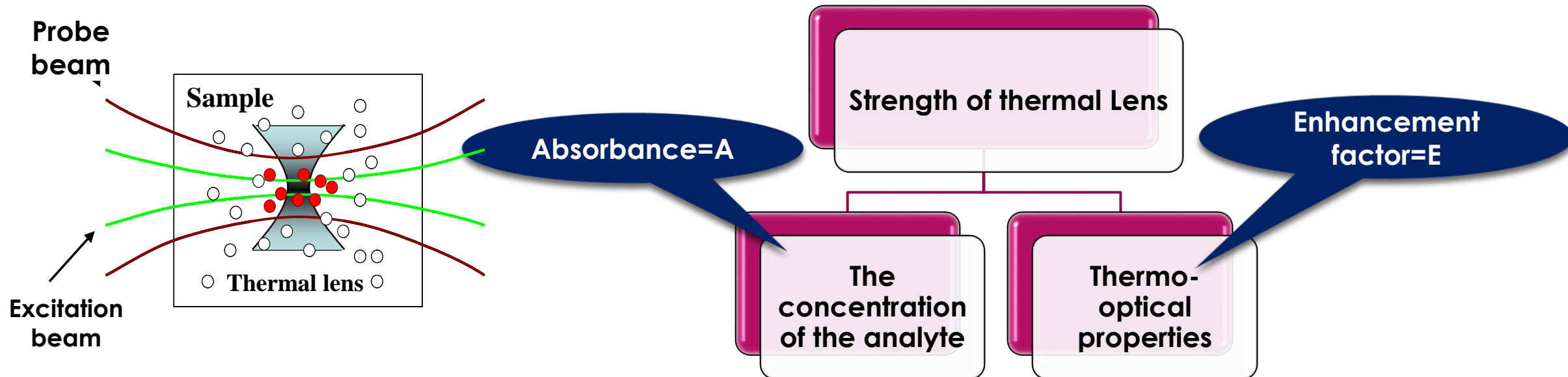
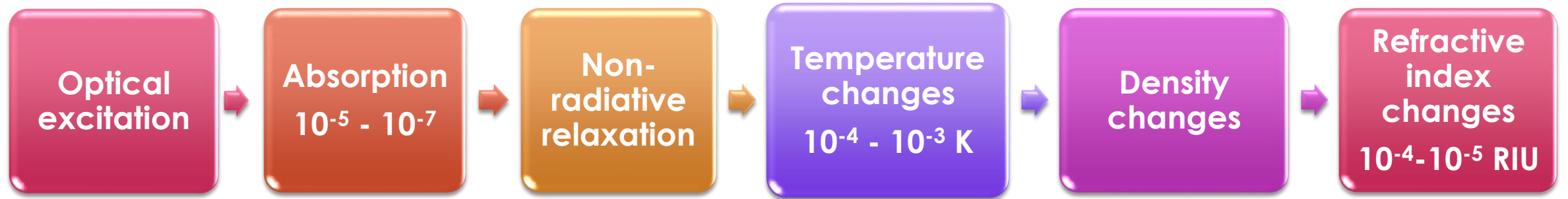


Research activities

Projects



Photothermal spectroscopy



Advantages of photothermal spectroscopy

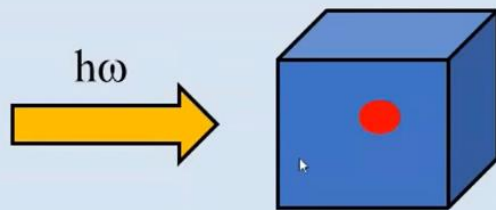
- ▶ Highly sensitive method
- ▶ Along with LIF are the best optical detection systems for microfluidics
- ▶ Free scattering method, so is important for nanoparticles
- ▶ On line detection
- ▶ Non destructive method
- ▶ Single molecular detection
- ▶ Cost efficient

TLS as a highly sensitive analytical method

Thermal lens spectroscopy (TLS)

In any light-matter interaction there is always a release of heat. The relaxation process is fast but the heat remains for a long time.

Consider one absorbing atom contained in 1 μL of water



Consider also that a beam of light illuminates the sample continuously. The atom will absorb one photon and will release the energy of this photon toward the surrounding water molecules (heating) in 10^{-10} - 10^{-13} s.

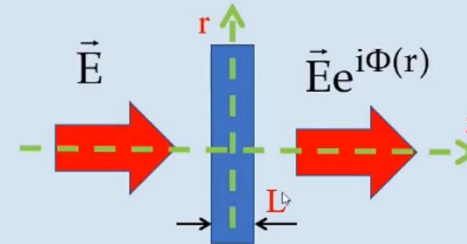
$$\frac{10^{-3}(s)}{10^{-11}(s)} = 10^8$$

TLS as a highly sensitive analytical method

**Photothermal method has a phase character.
The signal is in most of the cases proportional
to the change of phase**

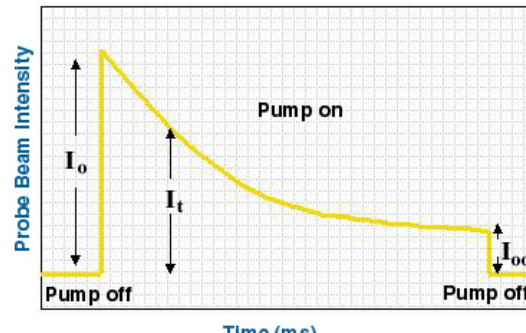
$$\Phi = 2\pi \frac{L}{\lambda} \left(\frac{\partial n}{\partial T} \right) \Delta T$$

Photo-thermal lens acts like a phase plate



$$\Phi(r) = \frac{2\pi}{\lambda} L \Delta n(r) \quad \Delta n(r) = \frac{\partial n}{\partial T} T(r)$$

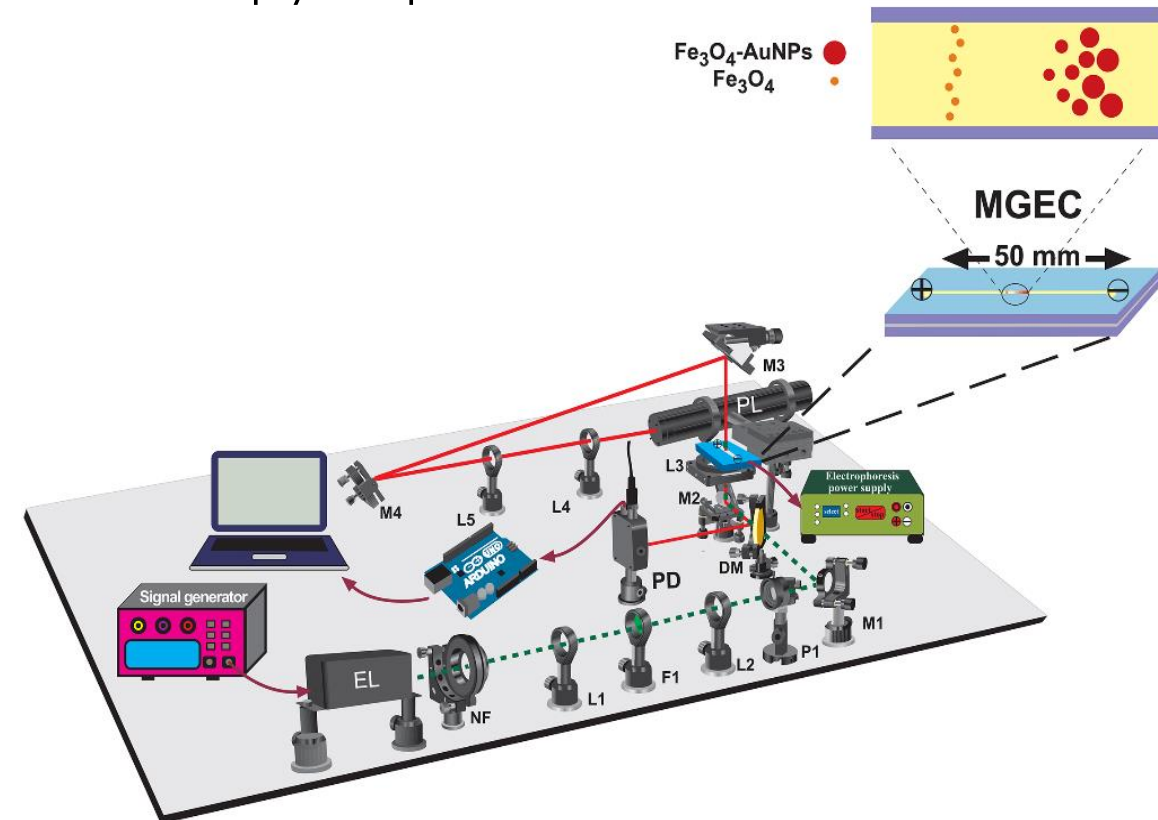
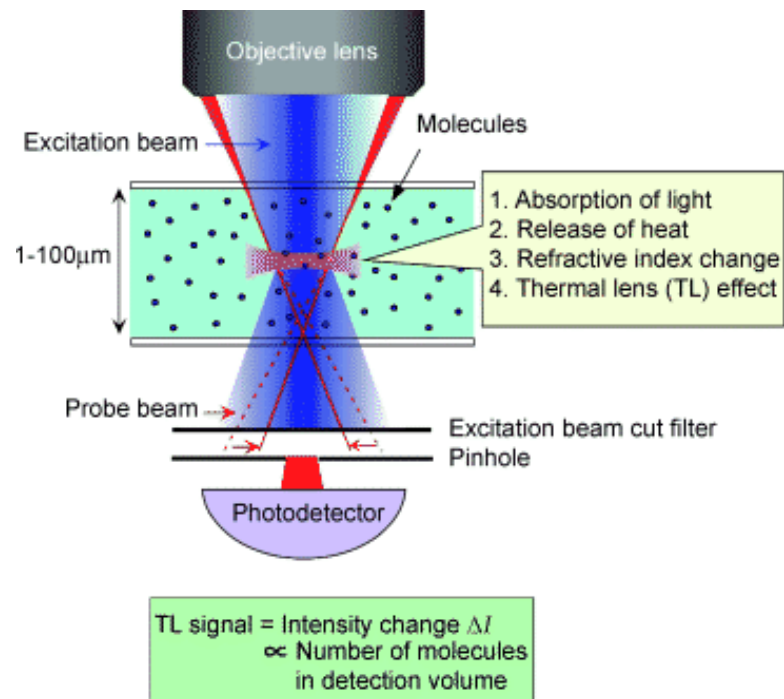
The change in temperature T is proportional to absorption α



$$PTLS_{signal} = \frac{I_0 - I_{\infty}}{I_{\infty}} = -2.303 \frac{(dn/dT)}{\lambda k} PA = EA$$

MGEC-TLS

Miniaturized Gel Electrophoresis-Thermal Lens Spectroscopy. Separation-detection



Advantages of MGEC-TLS

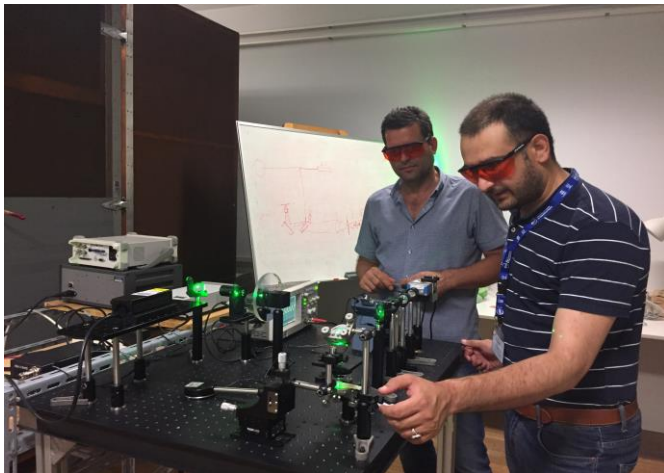
- ▶ Miniaturization of gel electrophoresis on a chip coupled with online thermal lens detection to separate and detect wide range of nanomaterials.

Advantages of microchip electrophoresis with thermal lens microscopy (TLM) detection:

- ▶ Uses reduced sample volume.
- ▶ Enables to parallelization analysis.
- ▶ Shortens analyses time for a given resolution.
- ▶ Takes advantage of an increased spatial and temporal resolution of TLM detection.
- ▶ Enables to detect fluorescent as well as non-fluorescent samples with highly sensitive TLM.

An Individual story

Jehan Akbar, Department of Physics, Hazara University, Khyber Pakhtunkhwa Region in Pakistan



ICO-ICTP Gallieno Denardo Prize recipient ICTP Associate

Career Development: While working with HC Jehan wrote a successful grant application to his regional government to set up the *first research laboratory* in his University based on the ICTP lab.

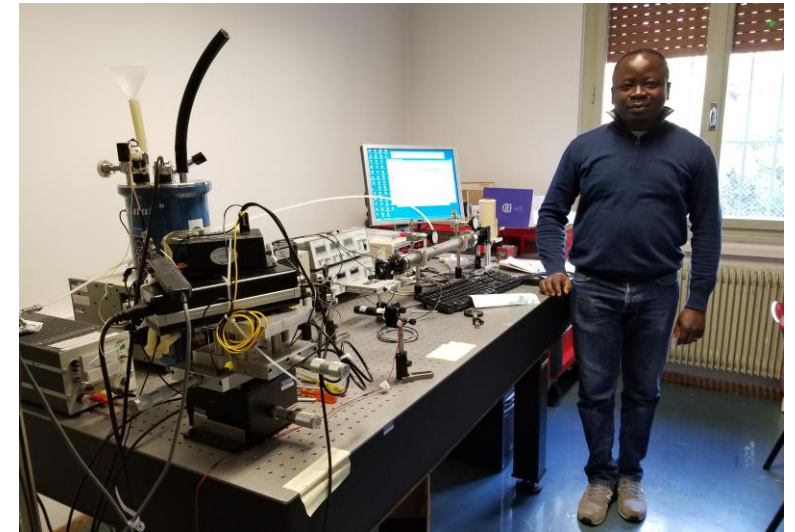
Papers:

- ✓ Humberto Cabrera, Jehan Akbar, Dorota Korte, Imrana Ashraf, Evelio E. Ramírez-Miquet, Ernesto Marín, Joseph Niemela, "**Absorption spectra of ethanol and water using a photothermal lens spectrophotometer**", Applied Spectroscopy 72(7), 1069-1073 (2018).
- ✓ Humberto Cabrera, Jehan Akbar, Dorota Korte, Evelio E. Ramírez-Miquet, Ernesto Marín, Joseph Niemela, Zeinab Ebrahimpour, Kasun Mannatunga, Mladen Franko, "**Trace detection and photothermal spectral characterization by a tuneable thermal lens spectrometer with white-light excitation**", Talanta 183, 158-163 (2018).
- ✓ H. Cabrera, I. Ashraf, F. Matroodi, E. E. Ramírez-Miquet, J. Akbar, J. J. Suárez-Vargas, J. F. Barrera Ramírez, D. Korte, H. Budasheva, J. Niemela, "**Photothermal lens technique: a comparison between conventional and self-mixing schemes**", Laser Physics 29 (5), 055703 (2019).

An African success story

Komlan Gadedjisso-Tossou, University of Lome, Togo

He wrote a successful grant application to The World Academy of Science (TWAS), and has set up a working lab in Togo borrowing from his experience at the ICTP Optics Lab.



- ✓ Lyubomir I. Stoychev, Humberto Cabrera, Jose J. Suarez-Vargas, Marco Baruzzo, Komlan S. Gadedjisso-Tossou, Ivaylo P. Nikolov, Paolo Sigalotti, Alexander A. Demidovich, Emiliano Mocchiutti, Cecilia Pizzolotto, Joseph Niemela, Guido Toci, Miltcho B. Danailov, Andrea Vacchi, "**DFG based MID-IR tunable source with 0.5 mJ energy and 30 pm linewidth**", Optics Letters 45(19), 5526 (2020).
- ✓ Komlan S. Gadedjisso-Tossou, Lyubomir I. Stoichev, Messanh A. Mohou, Humberto Cabrera, Joseph Niemela, Miltcho B. Danailov, Andrea Vacchi, "**Cavity ring-down spectroscopy for molecular trace gas detection using a pulsed DFB QCL emitting at 6.8 μm** ", Photonics 7(3), 74 (2020).

Research and Training for developing countries In 2021

Visitors

Behnaz Abbasgholi (Iran) 16/11/2020-16/02/2021

Fatima Matroodi (Iran) 1/02/2021-30/04/2021

Abdul Rahman (Pakistan) 1/04/2021-30/06/2021

Imrana Ashraf 1/08/2021-30/10/2021

Ali Reza Moradi 1/08/2021-30/10/2021

Sarah Kobe (Iran) 1/08/2021-30/10/2021

Alexis Jaramillo (Colombia) 10/06/2021-30/07/2021

Research and Training for developing countries In 2022

Visitors

Subhash Utadiya (India) 01/04/2022-16/08/2022

Masoomah Dashtdar (Iran) 27/06/2022-21/09/2022

Yamina Zaoui (Argelia) 04/10/2022-03/12/2022

Yurii Kotsiuba (Ukraine) 24/11/2022-24/12/2022

Success story

Behnaz Abbasgholi-NA, An former ICTP optics lab trainee, she is now doing research under supervision of Dr. Loredana Casalis in Nanoinnovation Lab at Elettra Synchrotron. The application of TLS for biosensing based nanoparticles is evolved to this research.

Papers:

- ✓ B. Abbasgholi N. A., Ahmed Asadig, Humberto Cabrera, **Online electrophoretic nanoanalysis using miniaturized gel electrophoresis and thermal lens microscopy detection**, Journal of Chromatography A, 1657, 462596 (2021).
- ✓ B. Abbasgholi N. A., Ahmed Asadig, Pietro Parisse, Loredana Casalis, Joseph Niemela, Stefano Bellucci, Humberto Cabrera, **“Miniaturized gel electrophoresis coupled with thermal lens microscope: a novel approach for monitoring DNA-coated gold nanoparticles surface”**, Microchemical Journal, 173 106961 (2021).
- ✓ Ahmed Alsadig, Behnaz Abbasgholi-NA, Hendrik Vondracek, Barbara Medagli, Sara Fortuna, Paola Posocco, Pietro Parisse, Humberto Cabrera and Loredana Casalis **“DNA-Directed Protein Anchoring on Oligo/Alkanethiol Coated Gold Nanoparticles: A Versatile Platform for Biosensing Applications”**, Nanomaterials, accepted (2022).



Success story

- ✓ Humberto Cabrera, Dorota Korte, Hanna Budasheva, Behnaz Abbasgholi N. Asbaghi, Stefano Bellucci, “**Through-Plane and In-Plane Thermal Diffusivity Determination of Graphene Nanoplatelets by Photothermal Beam Deflection Spectrometry**”, *Materials*, 14, 7273 (2021).
- ✓ Behnaz Abbasgholi-Na, Seyed Reza Nokhbeh, Osamah A Aldaghri, Khalid Hassan Ibnaouf, Nawal Madkhali, Humberto Cabrera, “**Thermal Diffusivity and Conductivity of Polyolefins by Thermal Lens Technique**”, *Polymers*, 14(13), 2707 (2022). DOI: 10.3390/polym14132707
- ✓ Behnaz Abbasgholi-NA, Osamah A Aldaghri, Khalid Hassan Ibnouf, Nawal Madkhali, Humberto Cabrera. “**On the Absorption and Photoluminescence Properties of Pure ZnSe and Co-Doped ZnSe:Eu³⁺/Yb³⁺ Crystals**”, *Applied Sciences* 12(9), 4248 (2022). DOI: org/10.3390/app12094248

Success story

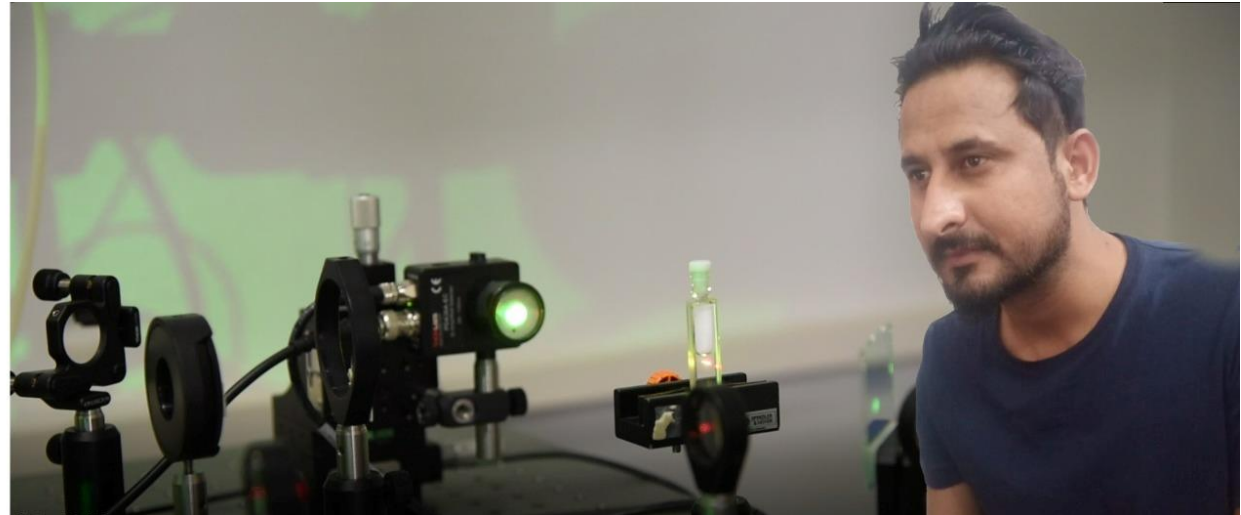
Abdul Rahman

PhD Thesis:

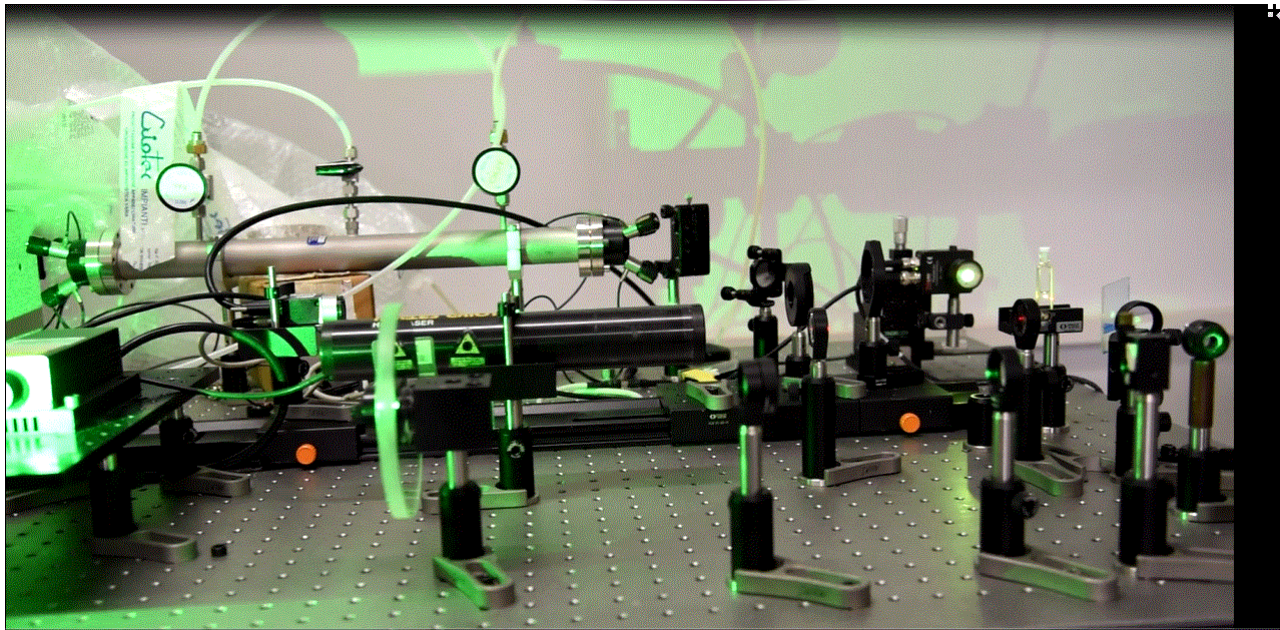
Thermal lens spectrometry using Gaussian and Laguerre Gaussian modes of excitation

Papers:

- ✓ Abdul Rahman, Humberto Cabrera, Muhammad Usman Malik, Imrana Ashraf, "**Laguerre-Gaussian induced temperature and refractive index profiles in thermal lens spectroscopy**", Journal of the Optical Society of America B, 38(1), 52 (2021).
- ✓ Abdul Rahman, , Kulsoom Rahim, Imrana Ashraf and Humberto Cabrera, "**A modified mode-mismatched thermal lens spectrometry Z-scan model: An exact general approach**", Optik 265(2), 169399 (2022). DOI: 10.1016/j.ijleo.2022.169399



Success story



Alexis Jaramillo Osorio, from University of Antioquia in Colombia has completed research for his PhD thesis.

- ✓ John Alexis Jaramillo Osorio, Alejandro Velez-Zea, Humberto Cabrera, Joseph Niemela, John Fredy Barrera-Ramírez, Roberto Torroba, "Optical encryption using phase modulation generated by thermal lens effect", *Journal of Optics* 24(2), 025702 (2022). DOI: 10.1088/2040-8986/ac4412

STEP: Sandwich Training and Education Program (IAEA-ICTP)

Subhash Utadiya

4.5-month visits each year for three years, with a second ICTP advisor, and access to journals, computing facilities, laboratories, etc.

- ✓ Subhash Utadiya, Vismay Trivedi, Gyanendra Sheoran, Atul Srivastava, Daniel Claus, Humberto Cabrera, Arun Anand, "**Digital holographic imaging of thermal signatures and its use in inhomogeneity identification**", Optics and Laser in Engineering 160, 107227 (2022). DOI: 10.1016/j.optlaseng.2022.107227



Summarizing activities

❖ Training

❖ Collaborations

INFN Trieste, INFN Frascati, the University of Nova Gorica in Slovenia, the National Institute for Research and Development of Isotopic and Molecular Technologies, Cluj-Napoca, Romania, Dr. Loredana Casalis (Elettra), University of Szeged, Hungary, Dr Zoltan Bozoki

❖ Advising Thesis

Abdul Rehman (Pakistan)
Alexis Jaramillo (Colombia)
Subhash Utadiya (India)

Impact of our research

- ✓ As a result of training with Jehan Akbar (associate and Tril fellow) and Komlan Gadedjisso-Tossou, two replicated Lab were set up in Pakistan and Togo, now giving training and research to master and PhD students there.
- ✓ Trainee visitors are in collaboration with us from their postdoc positions in different Universities
- ✓ More than 70 papers published in 7 years

Conferences and Schools

Winter Colleges on Optics since 2015. Strong emphasis on hands-on activities during the Optics College

ICPPP21 International Conference on Photoacoustic and Photothermal Phenomena 19-24 June, Vipava and Bled, Slovenia, <https://indico.ung.si/event/5/>

ICTP College on Optics: Theory and Applications of Lidar | (smr 3706)

STI Seminar: Digital holographic microscopy for single-shot quantitative phase contrast imaging of cells and their characterization <https://indico.ictp.it/event/9940/>

STI Seminar on Radial carpet and combined half-integer Bessel-like beams: generation, properties, and applications. <https://indico.ictp.it/event/10037/> (6 September 2022)

Future plan

- To introduce new projects based on optical methods for microfluidic systems,
- Nanobiosensors, and imaging systems
- To establish new Laboratories and collaborations in developing countries
- Advising PhD Thesis in developing countries (Step program)
- Training activities (TRIL program)
- To continue with international collaboration
- To apply for International projects to improve the facilities of the Lab and support visitors



Thanks for your attention