The Abdus Salam International Centre for Theoretical Physics

United Nations Educational, Scientific and Cultural Organization

IAEA International Atomic Energy Agency

2132-36

Winter College on Optics and Energy

8 - 19 February 2010

Solar energy strategy in AFRICA (part II)

A. Wague

University Cheikh Anta Diop
Dakar
SENEGAL

LAM

African Laser, Atomic, Molecular & Optical Sciences Network

THE AFRICAN LASER ATOMIC MOLECULAR AND OPICAL SCIENCES NETWORK (LAM NETWORK) ACTIVITIES FOR THE DEVELOPMENT OF OPTICAL SCIENCES AND THEIR APPLICATIONS IN AFRICA

A. Wague

University Cheikh Anta Diop, Dakar, Senegal

TSOSA MEETING

16 February 2010, ICTP,TRIESTE, ITALY

The LAM Network have been launched in Dakar, in 1991 at the occasion of the first International Workshop on the Physics and Modern Applications of Lasers organised by the Department of Physics at the University Cheikh Anta Diop of Dakar -Senegal. It was with the support of ICTP, Senegalese Government and French Embassy in Senegal

The main purpose of the Network is to promote the physics of lasers, atoms , molecules, optical sciences and their applications as well as to develop scientific co-operation in these fields in Africa

Structures of the Network

The Head quarter of the Network is localised at the Laboratory "Atomes Lasers" , an ICTP Affiliated Centre at the Faculty of Science and Techniques, University Cheikh Anta Diop of Dakar, Senegal.

Its directory include the President of the Network , regional co-ordinators, and international contacts.

The network involves scientists from almost all African countries.

Presently the LAM Network is one of the six ICO International Society Members including Optical Society of America (OSA), European Optical Society (EOS), International Society of Optical Engineering (SPIE) International Engineering Electrical and Electro-optical Society (EEE/LEOS), and Optics within life Sciences (OWLS).

LAM Network Web site: www.lamnetwork.org

IN RED DOTS LAM NETWORK REPRTESENATIONS IN AFRICA

IN BLUE DOTS LAMNETWORK INTERNATIONAL CONTACTS

ACTIVITIES OF THE NETWORK

I. Workshops

The LAM Network have already organised 9 International workshops on lasers and applications :

Dakar- Senegal in May 91,

- **Harare- Zimbabwe in September 93**
- **Cape Coast- Ghana in August 94,**
- **Khartoum- Sudan in January 96,**
- **Gaborone -Botswana in August 98,**
- **Tunis- Tunisia in December 2002 ,**
- **Douala- Cameroon in December 2004 .**
- **The 8th workshop was held in November 2007 in Cape Coast Ghana together with the Topical meeting of The International Commission of Optics and the OWLS meeting.**
- **The LAM 9 International workshop was held in Dakar from11 to 16 January 2010 together with the EBASI Conference and the NSBP meeting with the Launch of African Physical Society**

II. Schools and Conferences

>The first school in Optics was organised by the Network in Cap coast Ghana in 1993 in collaboration with ICO

>In addition in September 1996 and 1998 the LAM Network have organised schools in Optics in Abidjan Côte d'Ivoire.
>In 1998 in Dakar in Collaboration with the American Physical Society and European Physical Society , the Network have organised an International conference on Spectroscopy and Applications .

>in April 2000 The Network organised in collaboration with the International commission of Optics (ICO) , the optical Society of America (OSA) and the Abdus Salam International Centre for Theoretical Physics (ICTP) an international Conference on Optics for Sustainable Development in Dakar.

> In November 2001 in collaboration with ICS schools on optical design were organized in Dakar and Cape Coast
>In 2002 school in Optics and laser applications in Namibia

>In 2003 School on Bio photonics, at the University of Dakar.

III. Collaboration in Other African initiatives for the Development of Laser and Optical Sciences In Africa

>In 1999 collaboration with ICTP,Twas and LIS for Science literacy and Technology Education In Africa: Workshop Colours in Optics for high Schools teachers in Senegal

>In 2001, the LAM participated to the First meeting convey in Pretoria at the CSIR, aiming to the creation of a continental African laser centre at t In November 2003 in Johannesburg , the President of LAM pronounced the Launching speech of the African Laser Centre , an initiative for the development of laser infrastructure in Africa endorsed by African governments through NEPAD and financially supported for the moment only by South African Government. The President of the LAM is one of the Director on the ALC board of Directors and was a vice chair of ALC at his creation.

>In December 2004 and in April 2006 in Collaboration with Optical Society of Morocco, the Network have organised Schools in lasers and Applications in Tangier –Morocco.
>The LAM was also one of the initiator of the USA Africa meeting on Photon interaction with atoms held in Durban in South Africa in 2005 during the world year of Physics.

>And recently in January 2008, the LAM has participated in the USA Africa EBAL meeting in Cairo and has sponsored the LAPAM meeting in Algiers in June 2008.

IV. Training programs for the development of capacities building and Research in LAM Centres In Africa

1) **in collaboration with the Abdus Salam International Centre for Theoretical Physics (ICTP), Trieste Italy, the International Program for Physical Sciences, (IPPS) Uppsala, Sweden and Atomic Physics Division of Lund Institute of Technology Sweden, operational Laboratories in Diode Laser spectroscopy have been implemented in Senegal, Ghana, Sudan and Kenya in 1996, after intensive training in Lund, followed by the visit of Swedish scientist in all the four African countries**
2) **in the same framework, in 2001 in collaboration with the Lund Institute of Technology Laser Centre, the Network have participated in a one month workshop "Laser Spectroscopy in Development" in Lund Sweden with participants from Senegal, Ghana, Kenya, Sudan, Zimbabwe, Tunisia and Equador. The Workshop was an occasion for each country participant to build their own blue diode spectrometer to be taken at home after the workshop. This Spectrometer are operational in Africa, for example in Senegal in Photodynamic Therapy and Plant monitoring applications**
3)Recently in november 2009, Workshop on multispectral microscopy for medical diagnostic in Ghana in Colaboration with ISPand Lund University

V. Scientific Exchange Visiting Programs

The LAM Network is also developing programs of scientific exchange visit between different research institutions in Africa.

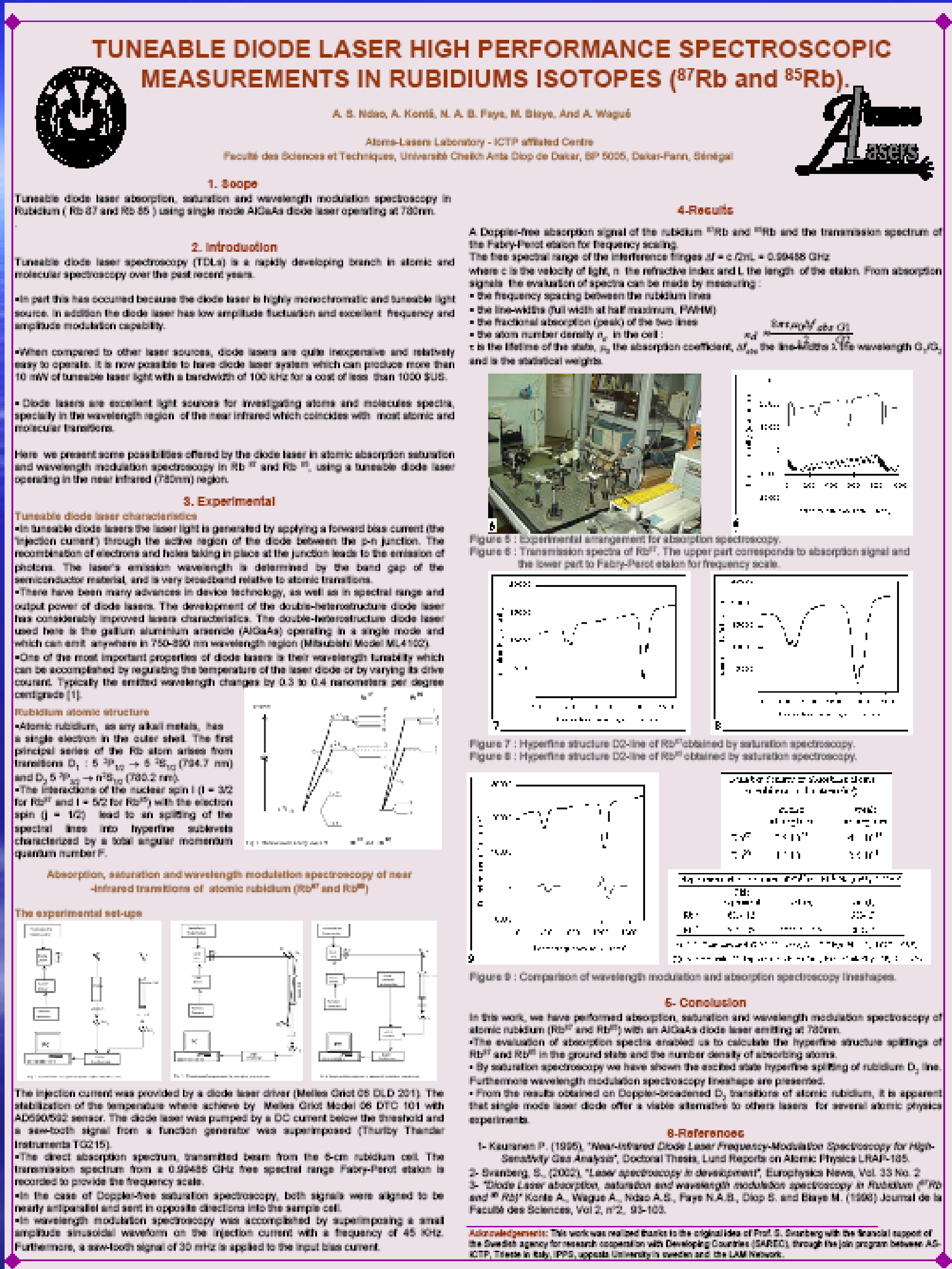
In this framework, several research co-operation and training visits of scientists from Mauritania, Mali , Cote d'Ivoire, Ghana, Cameroon and Sudan in the laboratory "Atomes Laser" at ICTP affiliated Centre in Dakar Senegal have been organised .

Similar visit of Scientists from Togo, Cameroon , Zimbabwe and Senegal to Cape Coast Ghana at the ICTP Affiliated Centre Laser and Fibre Optic Centre, have been also organised together with training visits of Scientists from Cameroon and Cote d'Ivoire in Tunisia .
In addition the CEPAMOQ in Duala Cameroon, one of the LAM network centre in Africa, have establish a strong collaborative scientific link with universities of the central African Zone in Congo , Gabon and Tchad by training students at Mphil and Ph.D level
Through its different activities the Network was able to contribute in showing the place and interest of the physics and applications of lasers in the reinforcement and development of scientific and technical training and research capabilities in optical sciences in Africa .

LAM Collaboration with ICO at ICO topical meeting in Senegal: Optics for sustainable Development

, Dakar April 2000

Diode laser Experiment at the Dakar ICTP affiliated and LAM Network Centre



TUNEABLE DIODE LASER HIGH PERFORMANCE SPECTROSCOPIC MEASUREMENTS IN RUBIDIUMS ISOTOPES (^{87}Rb and ^{85}Rb).

A. S. Ndao, A. Konté, N. A. B. Faye, M. Biaye, And A. Wagué

Atoms-Lasers Laboratory - ICTP affiliated Centre
Faculté des Sciences et Techniques, Université Cheikh Anta Diop de Dakar, BP 5005, Dakar-Fann, Sénégal

1. Scope

Tuneable diode laser absorption, saturation and wavelength modulation spectroscopy in Rubidium (Rb 87 and Rb 85) using single mode AlGaAs diode laser operating at 780nm.

2. Introduction

Tuneable diode laser spectroscopy (TDLs) is a rapidly developing branch in atomic and molecular spectroscopy over the past recent years.

•In part this has occurred because the diode laser is highly monochromatic and tuneable light source. In addition the diode laser has low amplitude fluctuation and excellent frequency and amplitude modulation capability.

•When compared to other laser sources, diode lasers are quite inexpensive and relatively easy to operate. It is now possible to have diode laser system which can produce more than 10 mW of tuneable laser light with a bandwidth of 100 kHz for a cost of less than 1000 $US.

• Diode lasers are excellent light sources for investigating atoms and molecules spectra, specially in the wavelength region of the near infrared which coincides with most atomic and molecular transitions.

Here we present some possibilities offered by the diode laser in atomic absorption saturation and wavelength modulation spectroscopy in Rb ^{87} and Rb ^{85}, using a tuneable diode laser operating in the near infrared (780nm) region.

3. Experimental

Tuneable diode laser characteristics

•In tuneable diode lasers the laser light is generated by applying a forward bias current (the "injection current") through the active region of the diode between the p-n junction. The recombination of electrons and holes taking in place at the junction leads to the emission of photons. The laser's emission wavelength is determined by the band gap of the semiconductor material, and is very broadband relative to atomic transitions.
•There have been many advances in device technology, as well as in spectral range and output power of diode lasers. The development of the double-heterostructure diode laser has considerably improved lasers characteristics. The double-heterostructure diode laser used here is the gallium aluminium arsenide (AlGaAs) operating in a single mode and which can emit anywhere in 750-890 nm wavelength region (Mitsubishi Model ML4102).
•One of the most important properties of diode lasers is their wavelength tunability which can be accomplished by regulating the temperature of the laser diode or by varying its drive courant. Typically the emitted wavelength changes by 0.3 to 0.4 nanometers per degree centigrade [1].

Rubidium atomic structure

•Atomic rubidium, as any alkali metals, has a single electron in the outer shell. The first principal series of the Rb atom arises from transitions D_1 : 5 $^2P_{1/2}$ → 5 $^2S_{1/2}$ (794.7 nm) and D_2 5 $^2P_{3/2}$ → $n^2S_{1/2}$ (780.2 nm).
•The interactions of the nuclear spin I (I = 3/2 for Rb^{87} and I = 5/2 for Rb^{85}) with the electron spin (j = 1/2) lead to an splitting of the spectral lines into hyperfine sublevels characterized by a total angular momentum quantum number F.

Absorption, saturation and wavelength modulation spectroscopy of near -infrared transitions of atomic rubidium (Rb^{87} and Rb^{85})

The experimental set-up

The injection current was provided by a diode laser driver (Melles Griot 06 DLD 201). The stabilization of the temperature where achieve by Melles Griot Model 06 DTC 101 with AD590/592 sensor. The diode laser was pumped by a DC current below the threshold and a saw-tooth signal from a function generator was superimposed (Thurlby Thandar Instruments TG215).
•The direct absorption spectrum, transmitted beam from the 5-cm rubidium cell. The transmission spectrum from a 0.99455 GHz free spectral range Fabry-Perot etalon is recorded to provide the frequency scale.
•In the case of Doppler-free saturation spectroscopy, both signals were aligned to be nearly antiparallel and sent in opposite directions into the sample cell.
•In wavelength modulation spectroscopy was accomplished by superimposing a small amplitude sinusoidal waveform on the injection current with a frequency of 45 KHz. Furthermore, a saw-tooth signal of 30 mHz is applied to the input bias current.

4-Results

A Doppler-free absorption signal of the rubidium ^{87}Rb and ^{85}Rb and the transmission spectrum of the Fabry-Perot etalon for frequency scaling.
The free spectral range of the interference fringes $\Delta f = c/2nL$ = 0.99455 GHz
where c is the velocity of light, n the refractive index and L the length of the etalon. From absorption signals the evaluation of spectra can be made by measuring :
• the frequency spacing between the rubidium lines
• the line-widths (full width at half maximum, FWHM)
• the fractional absorption (peak) of the two lines
• the atom number density n_d in the cell :
τ is the lifetime of the state, α_0 the absorption coefficient, Δf_{abs} the line-widths λ the wavelength G_1/G_2 and is the statistical weights.

Figure 5 : Experimental arrangement for absorption spectroscopy.
Figure 6 : Transmission spectra of Rb^{87}. The upper part corresponds to absorption signal and the lower part to Fabry-Perot etalon for frequency scale.

Figure 7 : Hyperfine structure D2-line of Rb^{87} obtained by saturation spectroscopy.
Figure 8 : Hyperfine structure D2-line of Rb^{85} obtained by saturation spectroscopy.

Figure 9 : Comparison of wavelength modulation and absorption spectroscopy lineshapes.

5- Conclusion

In this work, we have performed absorption, saturation and wavelength modulation spectroscopy of atomic rubidium (Rb^{87} and Rb^{85}) with an AlGaAs diode laser emitting at 780nm.
•The evaluation of absorption spectra enabled us to calculate the hyperfine structure splittings of Rb^{87} and Rb^{85} in the ground state and the number density of absorbing atoms.
• By saturation spectroscopy we have shown the excited state hyperfine splitting of rubidium D_2 line. Furthermore wavelength modulation spectroscopy lineshape are presented.
• From the results obtained on Doppler-broadened D_2 transitions of atomic rubidium, it is apparent that single mode laser diode offer a viable alternative to others lasers for several atomic physics experiments.

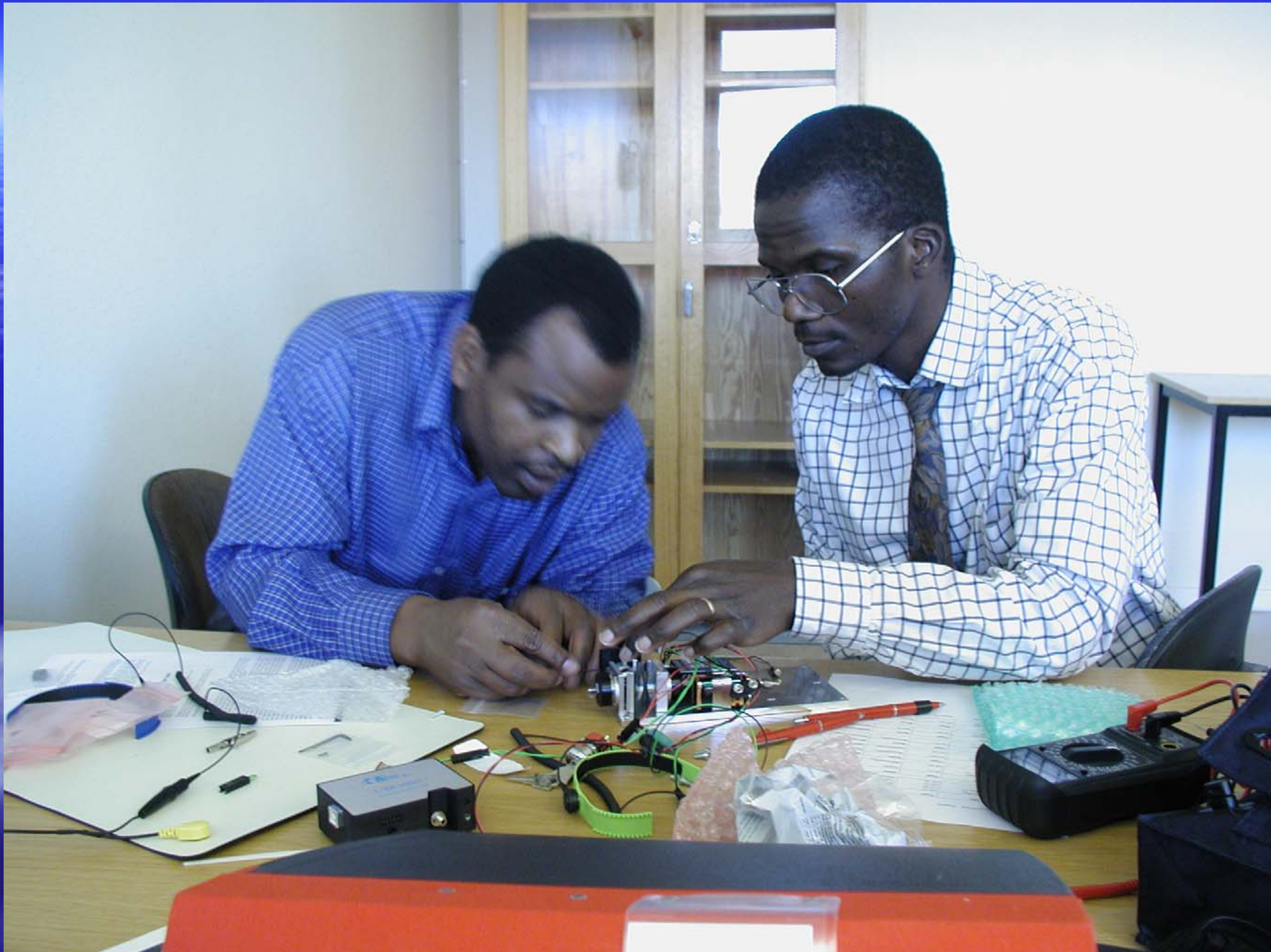
6-References

1- Kauranen P. (1996), *"Near-Infrared Diode Laser Frequency-Modulation Spectroscopy for High-Sensitivity Gas Analysis"*, Doctoral Thesis, Lund Reports on Atomic Physics LRAP-185.
2- Svanberg, S., (2002), *"Laser spectroscopy in development"*, Europhysics News, Vol. 33 No. 2
3- *"Diode Laser absorption, saturation and wavelength modulation spectroscopy in Rubidium (^{87}Rb and ^{85} Rb)"* Konte A., Wague A., Ndao A.S., Faye N.A.B., Diop S. and Biaye M. (1998) Journal de la Faculté des Sciences, Vol 2, n°2, 93-103.

Acknowledgements: This work was realized thanks to the original idea of Prof. S. Svanberg with the financial support of the Swedish agency for research cooperation with Developing Countries (SAREC), through the join program between AS-ICTP, Trieste in Italy, IPPS, uppsala University in sweden and the LAM Network.

LUND/LAM Workshop: team from Ghana July 2001

LUND/LAM Workshop: team from Zimbabwe, July 2001



ANALYSIS OF LASER INDUCED CHLOROPHYLL FLUORESCENCE

A. S. Ndao, A. Konté, N. A. B. Faye, M. Biaye and A. Wagué

Atoms-Lasers Laboratory - ICTP affiliated Centre
Faculté des Sciences et Techniques, Université Cheikh Anta Diop de Dakar, Dakar-Fann, Sénégal

1. Scope

- Measurement of laser induced chlorophyll fluorescence (LICF) emission spectra of leaves
- Analysis of the plants stress using LICF curve-fitted parameters

2. Introduction

Monitoring of vegetation by spectroscopic detection of electromagnetic radiation is a powerful non-contact and non-destructive method in the study of environment. In particular laser induced fluorescence spectroscopy of terrestrial vegetation is an important aspect of active remote sensing which provides a specific tool for assessing vegetation damage and forest decline]. within plant tissue, the light energy (in the region of 400 – 800 nm) absorbed by photosynthetic pigments (chlorophylls a, b and carotenoids) is mainly used to drive the photosynthetic processes which provide chemical energy for plant's growth when under optimum conditions the largest part of the absorbed light energy is used for CO_2 fixation in the Calvin cycle. Part of absorbed energy is lost during the migration from the pigment antenna to the reaction centres and can be dissipated by a variety of non-photochemical processes. Such processes include the emission of heat and re-emission of small (2-5% of the absorbed light energy) but diagnostically significant amounts of the absorbed radiation [1]. This reemission which occurs at longer wavelength in the red (680nm) and far-red (735nm) is termed as Chlorophyll Fluorescence. The capacity of a plant for photochemistry is limited and will depend upon a range of factors including stresses caused by environmental conditions. If photosynthetic processes are very active then red fluorescence at 690nm as well as the fluorescence intensity ratio (FIR) of the chlorophyll bands F690/F735 will be low. Conversely if these processes are inactive or impaired then red fluorescence and (FIR) increase.

These facts enable chlorophyll fluorescence to be used as a standard method for investigating plant class differentiation, chlorophyll contents monitoring and plant stresses detection (water deficit, temperature, nutrient deficiency, polluting agents, attack by pathogens, etc.). Such studies require a priory a basic knowledge of fluorescence signature of leaves.

Here we present some results concerning LICF of some tropical plants as well as the FIR obtained from LICF curve-fitted parameters and correlated to the chlorophyll content.

3. Experimental

Materials

Four plant species are collected in August, at the beginning of the raining season, in the botanical garden of Cheikh Anta DIOP University in Dakar-Senegal :

- Moringa oleifera • Azadirachta indica • Hibiscus subdariffa • Adansonia digitata.

LICF measurements

The chlorophyll fluorescence were measured under steady state conditions, i.e., 5mn after onset of the excitation light. Excitation and sensing of the chlorophyll fluorescence were performed on each leaf surface, either upper or lower leaf side.

The experimental apparatus is constituted by a compact fluorosensor [2] based on a violet diode laser and an integrated spectrometer assembled at the Lund Institute of Technology by two of the authors during the workshop on Laser spectroscopy in development.

The light source of the fluorosensor is a continuous-wave violet semiconductor with nominal wavelength at 25°C of 396 nm and output power of 5mW.

Since the spectrometer is fiber-coupled, the LICF light is focused by a fiber port into a short fiber which is connected to the 100 µm entrance slit of the miniature spectrometer (Ocean Optics S2000). The Miniature Fiber Optic Spectrometer communicate with a portable PC via an external analog-to-digital converter and is supported by OOIbase32TM, the Windows-based operating software.

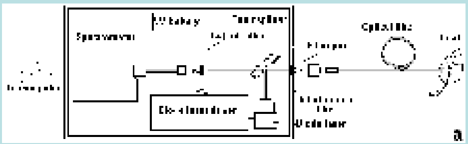


Figure 1.a : Schematic lay-out of the compact fluorosensor inducing LICF.

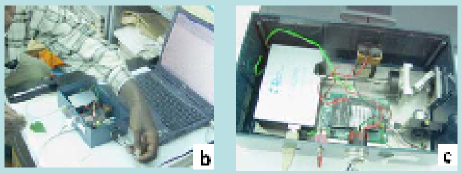
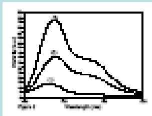


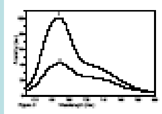
Figure 1. : (b) Photograph of the system inducing LICF, (c) Photograph of the interior .

4-Results

Chlorophyll fluorescence emission spectra

Excited at 396 nm, plants exhibit a fluorescence mainly in the 650-800 nm region. This LICF have a maximum in 680-700 nm (F690), and a shoulder in 730-740 nm (F735).





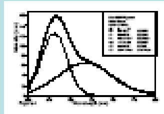


Figure 2: Chlorophyll fluorescence emission spectra of yellow (1) light-green (2), fully-green (3) leaves of Azadirachta indica, excited at 396 nm and sensed from the upper leaf side in the steady state conditions.

Figure 3: Violet excited chlorophyll fluorescence emission spectra lower (1) and upper (2) leaf side of Azadirachta indica light-green leaf excited at 396 nm and sensed in steady state conditions.

Figure 4: The Gaussian deconvolution of upper leaf side chlorophyll fluorescence emission spectra of fully-green leaf of Hibiscus sabdariffa.

- For very low concentration of chlorophyll pigments as in light-green leaves, the fluorescence intensity will be roughly proportional to the amount of chlorophyll in the leaves.
- In Yellow leaves the spectrum exhibit a low maximum near 682 nm and a strong reduction in the F740 nm fluorescence shoulder in relation to the 682 nm peak.
- The expansion of the shoulder proceeds with increasing chlorophyll content. However, for higher concentrations, corresponding to fully-green to dark-green leaves the chlorophyll fluorescence will decrease considerably (partial overlapping of the absorption spectrum of green leaves with the fluorescence spectrum).
- In order to find the exact peak position, the peak amplitude, the band width and the band area, the measured fluorescence emission spectra are analysed by fitting the curves with Gaussian spectral functions.

Analysis of the LICF spectra by FIR

- The absolute fluorescence usually varies to a large degree from sample to sample (excitation and sensing angles of the fluorescence, and the roughness and scattering properties of the leaf surface) than the fluorescence ratio.
- The LICF spectra can be analyse by Fluorescence Intensity Ratio F690/F735 calculated from the spectral intensity obtained from curve-fitted parameters.

[illegible]	1,20	[illegible]	[illegible]	[illegible]	[illegible]	2,04	[illegible]	0,44	[illegible]
[illegible]	2,24	2,17	2,90	2,05	[illegible]	2,40	[illegible]	[illegible]	[illegible]
[illegible]	2,00	1,24	[illegible]	1,59	[illegible]	2,02	[illegible]	[illegible]	[illegible]
[illegible]	1,69	2,00	[illegible]	[illegible]	[illegible]	0,77	0,18	1,10	0,38

Table 1: Upper Leaf Side Curve-Fit Parameters of Adansonia digitata, Hibiscus sabdariffa, Moringa oleifera, and Azadiracha indica [3].

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	2,54	[illegible]	[illegible]	2,44	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	2,00	[illegible]	1,60	[illegible]	[illegible]	[illegible]	[illegible]	0,49	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Table 2: Lower Leaf Side Curve-Fit Parameters of Adansonia digitata, Hibiscus sabdariffa, Moringa oleifera, and Azadiracha indica [3].

- Under many stress conditions that last for a long time, the chlorophyll content peer leaf area unit become lower than in normal green leaves.
- A increased ratio F690/F735 is not only indicative of a lower chlorophyll content; the values also increase when the process of photosynthetic electron conversion is affected and decline.

5- Conclusion

- In nature under longer-lasting stress conditions, the plants are characterised mainly by a lower chlorophyll content peer leaf area unit is lower and also by the decline of the rate of photosynthesis.
- The fluorescence ratios proved to be very early stress and strain indicators.
- Although one cannot identify a stressor by fluorescence measurements alone, one can however, considerably reduce the number of possible stress constraints to a few.
- Our results based on the 396 nm excitation, provide new data and new calibration of the intensity ratios as indicators of the plant physiological state.

6-References

1- Lichtenthaler, H. K., and Rinderle, U. (1988), "*The role of chlorophyll fluorescence*", In : the detection of stress conditions in plants. CRC Crit. Rev. Anal Chem. 19 (supp. 1) : 29-85.
2- Svanberg, S., (2002), "*Laser spectroscopy in development*", Europhysics News, Vol. 33 No. 2
3- Ndao A.S., Konté A., Biaye M., Faye M. E., Faye N.A.B and Wague A. (2005), "*Analysis of Chlorophyll Fluorescence Spectra in Some Tropical Plants*" Journal of Fluorescence, Vol 15, No.2

Acknowledgements: The authors gratefully acknowledge Prof. S. Svanberg at the Department of Physics of the Lund Institute of Technology-Sweden, Prof G. Denardo at the SA-ICTP in Trieste-Italy and the IPPS in Upsala-Sweden.

PHOTODYNAMIC THERAPY AND FLUORESCENCE DIAGNOSTIC IN HUMAN MALIGNANCIES

A. S. Ndao[1], A. Konté[1], N. A. B. Faye[1], M Blaye and A. Wagué[1]
Svanberg[3] k, Svanberg[3] C. and Bendsoe[3] N.
Diop[2] M.

1. Atoms-Lasers Laboratory - Faculté des Sciences et Techniques, Université Cheikh Anta Diop de Dakar, BP 5005, Dakar-Fann, Sénégal
2. Departments of Oto-Rhino-Laryngology / Ear-Nose-Throat and Dermatology at the Aristide le Dantec University Hospital, Dakar, Senegal
3. Lund Laser Centre / Lund University Medical Laser Centre , Lund – Sweden

1. Scope

- Blue laser-induced Fluorescence (LIF) signatures from measurements on human premalignant skin lesions prepared with δ-aminolevulinic acid (ALA).
- photodynamic therapy utilising δ-aminolevulinic acid-induced protoporphyrin photosensibilisation with laser light at 635nm in skin malignancies.

2. Introduction

Fluorescence diagnostic techniques allows to catch cancer earlier, increasing the likelihood of successful treatment. This makes the LIF cancer diagnostic to be a very promising tools for Africa, as we know that in developing countries many tumours are already at discovery at the late stage and therefore difficult to treat.

Even if laser photosensitization-based therapy named photodynamic therapy is possible, unfortunately, a few number of people are eligible for treatment in this manner in Africa.

Photodynamic therapy (PDT) combines a drug (called a photosensitizer or photosensitizing agent) with a specific type of light to produce a form of oxygen that kills nearby cells. Each photosensitizer is activated by light of a specific wavelength. This wavelength determines how far the light can travel into the body. Thus, specific photosensitizers and wavelengths of light are used to treat different areas of the body with PDT. In addition PDT is a minimally invasive tumour treatment modality with high tumour selectivity.

Here the technology employed for the Fluorescence signatures of human malignancies is diode laser spectroscopy, which provides state-of-the-art scientific and technological possibilities while remaining on a realistic cost level.

The method relies on the selective transfer of triplet to singlet oxygen and the generation of other free radicals mediated by the blue laser excitation of the ALA sensitising agent, which normally is retained to higher degree in the malignant tissue compared to the normal non-diseased tissue.

Some results concerning Laser-induced Fluorescence (LIF) monitoring and Therapy (PDT) in the detection and treatment of human malignancies are presented herein.

3. Detection of Human Malignancies

Material

- The Dakar fluorosensor (Figure 1.a), resulting from the Lund workshop, was used in the detection and treatment of human malignancies.

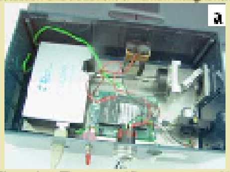



Figure 1.a : The compact fluorosensor used to induce skin fluorescence.

Figure 1.b : Participants from Kenya, John Kimari Wangai and Senegal, Almamy Konte and Ahmadou Wagué, in the Lund/African LAM-Net workshop, building and integrating a diode laser based fluorosensor at the Department of Physics, Lund University.

LIF detection of Human Malignancies

Within a few (3-4 hours) an accumulation of ALA occurs intracellularly. The blue continuous laser light (396nm -3mW) of the compact fluorosensor is directed through a fiber optic cable to the tumours surface where ALA is transformed to the highly fluorescent and photodynamically active protoporphyrin IX (PpIX) via the heam cycle. The PpIX build-up seems to be increased in highly proliferating tissue as malignant cells, which can be explained by changes in the enzyme activity [1]. The LIF light is focused into a short fiber which is connected to the 100 µm entrance slit of a S2000 Ocean Optics miniature spectrometer. The Spectrometer communicate with a portable PC via an external analog-to-digital converter. The Windows-based operating software OOIbase32TM supplies all scanning, time-based, and accessory data acquisition as well as control of all hardware. The PpIX is characterised by a dual-peaked fluorescence emission at about 635 and 705 nm. when excited in the blue wavelength range.

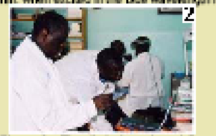
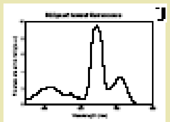



Figure 2 : The diode laser based fluorosensor being adjusted by Ababacar Ndao. The optical fibre for excitation light and detection of the fluorescence is seen in the hand of Ahmadou Wagué.

Figure 3 : *In vivo* fluorescence spectra. in connection with ALA-PDT treatment at the ENT clinic. The build-up of the ALA-induced PpIX is clearly seen with a dual peaked fluorescence signal (about 635 and 705 nm) before PDT.

4- photodynamic therapy

Material

- For the PDT treatment [2], a Light Emitting Diode (LED) equipment, donated from PhotoCure, Oslo, Norway, was brought to Senegal and mounted at the ENT department at the Aristide le Dantec University Hospital (Figure 5). The photosensitizing agent (ALA - δ amino levulinic acid) and medical disposals were carried from the Lund University Medical Laser Centre by Niels Bendsoe and Katarina Svanberg.
- The LEDs have emission at 635 nm to match the absorption peak of the ALA-induced Protoporphyrin IX (PpIX), which is a very potent photosensitizing drug.


Figure 4 : ALA preparation for clinical use. The vial of 1.5 gram ALA (Meddac, GmbH, Hamburg, Germany) is dissolved in few drops of saline (left) and mixed and mixed into Essex creme® to a concentration by weight to 20% ALA (right). The doctors are assisted by Kristina Svanberg.

Figure 5 : Mounting of the Light Emitting Diode (LED) irradiation unit at the ENT department in Dakar. Discussions on the handling of the LED equipment in clinical practice .

PDT treatment of Human Malignancies

- In connection with the PDT treatment the diode laser-based fluorosensor was used for monitoring the build up of the ALA-induced PpIX in the tumour area and surrounding skin. The PDT-induced photobleaching of PpIX was also detected by laser-induced fluorescence measurements.
- It was clearly stated before the treatment, that ALA-induced PpIX, with an absorption at 635 nm is not the optimal sensitizing agent for heavily pigmented tumours. However, even without an optimal wavelength, a tumour response is observed, which of course was promising.
- For the future, it would be of interest to use sensitizing agent with absorption at approximately 700 nm for heavily pigmented tumours.
- Treated Patients should avoid direct sunlight and bright indoor light for at least 6 weeks after treatment.

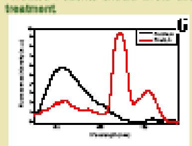
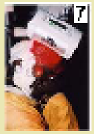




Figure 6 : *In vivo* fluorescence spectrum post PDT, recorded from the patient with malignant cylindroma, shows the photo-induced bleaching of the active agent PpIX.

Figure 7 : The patient is treated for a tumour mass in the scalp. Niels Bendsoe is performing the treatment procedure with a total light dose of 60 Joule/cm^2. Ababacar Ndao (in the background) was performing the laser-induced fluorescence measurements with the diode laser based fluorosensor.

Figure 8 : malignant melanoma tumour located on the foot sole of a young female patient. ALA-PDT was performed. The foot sole with the tumour is seen before (left) and 2 days after the ALA-PDT procedure (right). A slight tumour reduction was achieved.

6- Conclusion

- The first ALA-PDT in Senegal where perform in a few patients but demonstrate the procedure from mixing the ALA to illuminating the tumours. ALA-PDT with topical application is a practical treatment modality without any toxic side effects. It is easy to handle in clinical settings, where the infrastructure is less developed.
- PDT is a local treatment and generally cannot be used to treat cancer that has spread (metastasized)
- Researchers continue to study ways to improve the development of photosensitizers that are more specifically target cancer cells. Other research is focused on the ways to improve equipment and the delivery of the activating light that can penetrate tissue and treat deep or large tumors [5].
- PDT has the potential of being a very attractive treatment modality for developing countries.

8-References

1- Navone NM, Frisardi AL, Resnik ER, Del C.Batlle AM and Polo CF(1988), *"Porphyrin biosynthesis in human breast cancer Preliminary mimetic in vivo syudies"*, Med Sci Res 16 : 61-62.

2- Wilson BC. *"Photodynamic therapy for cancer : Principles"* Canadian Journal of Gastroenterology 2002;16(6):393–396.

3- Dickson EFG, Goyan RL, Pottier RH. (2003) *"New directions in photodynamic therapy"* Cellular and Molecular Biology; 48(8) : 939–954.

Acknowledgements: We gratefully acknowledge the Office of External Activities of AS-ICTP –Trieste Italy, the IPPS - Uppsala, the SAREC/SIDA - Stockholm, and the Lund Laser Centre / Lund University Medical Laser Centre - Sweden.

Lund /LAM Workshop at Lund Medical Laser Centre ,July 2001

Preparation for PDT Session at Dakar University Hospital Le Dantec,
Dakar, January, 2003

PDT session at Dakar University hospital Senegal

School on Biophotonics,

Dakar ,January 2003

COLLABORATION IN LIBS EXPERIMENT AT LAM CENTRE ”ATOMES LASERS LABORATORY”

DAKAR, SENEGAL, June 2008

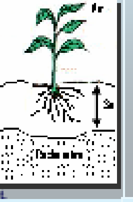
DETECTION DE METAUX LOURDS DANS LES PLANTES PAR SPECTROSCOPIE DU PLASMA INDUIT PAR LASER (LIBS)

A. S. Ndao[1], A. Konté[1], T. Gasmi[2] And A. Wagué[1,3]

1. Atoms-Lasers Laboratory - ICTP affilated Centre, Faculté des Sciences et Techniques, Université Cheikh Anta Diop de Dakar, Dakar-Fann, Sénégal.
2. Saint Louis University in Spain, Madrid Campus, Espagne.
3. Institut de Technologie Nucléaire Appliquée, ITNA

1. Introduction

- Dans les domaines de l'analyse, du contrôle et de la mesure physique, le laser constitue un outil métrologique particulièrement puissant et polyvalent, capable d'apporter des réponses concrètes à des problématiques variées, y compris d'ordre sociétal.
- La spectroscopie du plasma induit par laser (LIBS) est une technique d'analyse multiéléments, rapide, compacte et ne nécessitant qu'une préparation minimale de l'échantillon (liquide solide ou gazeux) . La spectroscopie LIBS a des applications dans des domaines très étendus : sciences de l'environnement, sciences biomédicales et pharmaceutiques, industrie, applications militaires ….
- La contamination de l'environnement par les métaux lourds est un enjeu de santé publique important. La spectroscopie LIBS permet de réaliser des mesures de la teneur en métaux lourds à l'échelle de quelques ppb.
- Des mesures quantitatives et qualitatives sont en cours au Laboratoires Atomes Lasers sur des plantes exposés à la pollution urbaine.



►Origine des métaux lourds dans les sols :

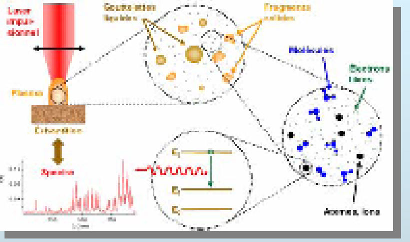
Naturelle :
- altération de la roche-mère,
- transferts dans le sol et à sa surface,
- apports atmosphériques (volcans…)

Anthropique :
- agriculture (épandages, engrais),
- contaminations ponctuelles (industries),
- contaminations diffuses (circulation automobile, précipitations…)

► Les métaux lourds : un danger pour la santé et l'environnement.

Figure 3 Dispositif experimental LIBS 2500 Ocean Optics au Laboratoire Atomes Lasers de l'UCAD

2. Principe de la spectroscopie du plasma induit par laser



Dynamique de la formation du plasma :
- Absorption des photons par les électrons (<1 fs)
- Thermalisation des électrons (100 fs)
- Refroidissement des électron et transfert d'énergie vers les atomes neutres et les ions (1 ps)
- Diffusion thermique dans le matériau (10 ps)
- Début de la fusion du matériau et de l'ablation (100 ps)
- Début de la formation du plasma LIBS (1ns)
- Ejection de particules « lourdes » (100 ns)

Mécanismes de formation du plasma dépend du temps de relaxation électrons/réseau τ_{ei} par rapport à la durée d'impulsion τ :
- $\tau_{ei} >> \tau$ (fs) ⇒ mécanisme dominant : ionisation
- $\tau_{ei} << \tau$ (ns) ⇒ équilibre thermique dynamique laser/matériau

A l'Équilibre Thermodynamique Local (ETL) :
- Processus radiatifs dans le plasma négligeables devant les processus collisionnels
recombinaison radiative << ionisation collisionnelle
- Ces processus sont rapides devant le temps caractéristique de variation de la température *Te* et de la densité d'électrons *Ne*
taux d'ionisation << temps caractéristique d'expansion du plasma

Te satisfait aux relations de Boltzmann et de Saha Te et Ne varient lentement par rapport au temps de la mesure

3. Quelques résultats préliminaires

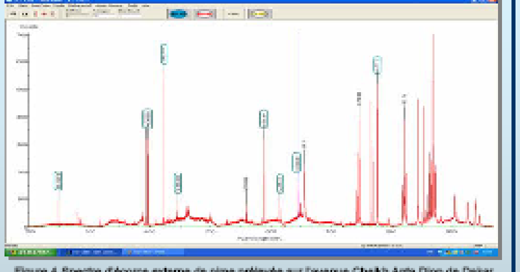


Figure 4 Spectre d'écorce externe de nime prélevée sur l'avenue Cheikh Anta Diop de Dakar

4. Perspectives

Avec la technique de la spectroscopie LIBS, les perspectives sont très grandes pour des applications très diversifiées surtout dans les domaines des sciences de l'environnement, des sciences biomédicales et pharmaceutiques ainsi que dans l'industrie.

Notre laboratoire est ouvert à toute collaboration dans ces différents domaines d'applications des lasers pour le développement socio-économique et pour le progrès de la science et de la technologie en Afrique.

5. References

1. Andrzej W. Miziolek, Vincenzo Palleschi and Israel Schechter. *Laser induced Breakdown spectroscopy*, Cambridge University Press, 2006
2. Fang-Yu Yueh, Jagdish P. Singh, and Hansheng Zhang, in *Encyclopedia of analytical Chemistry*, J. Photochim. R.A. Meyers (Ed), pp. 2066 -2087 © John Wiley & Sons Ltd, Chichester, 2000.
3. F. Hilbk-Kortenbruck, R. Noll, P.Wintjens, H. Falk, and C. Becker, *Analysis of heavy metals in soils using laser-induced breakdown spectrometry combined with laser-induced fluorescence*. Spectrochim. Acta Part B, 56 933–945, 2001.

Remerciements :

Le Laboratoire Atomes Lasers remercie le Programme International en Sciences Physiques à l'Université d'Upsala en Suède sous le sponsoring de SIDA-SAREC ainsi que le Centre International de Physique Théorique Abdou Salam de Trieste (ICTP) pour leur soutien.

Wokshop on multispectral microscopy , Cape Coast , November 2009

LAM 7 meeting in Douala Cameroon(December 2004)

LAM8 and ICO Topical Meeting in Ghana (November 2007)

LAM8-ICO Meeting in Ghana : Walk above the jungle

Delegates at the LAM 9 at the Presidential Palace With the President of Republic of SENEGAL 11January 2010


EBASI
onférence Internationale LAM9 /EBASI /NSBP sur les "Lasers et l'Optique en Scie
Technologie" et sur "Science et Technologie pour un Développement Durable"
Lancement officiel de la Société Panafricaine de Physique
Sous le Haut Patronage du Président de la République Maitre Abdoulaye WADE
11 - 16 JANVIER 2010
AIP
APS
ISP
IOP
alc

Photo during AfPS meeting , Dakar 14 January 2010

SPONSORING and PERSPECTIVES

The Activities of the LAM Network are mainly sponsored by ICTP, IPPS and during workshops and schools by governmental and universities authorities of African countries in which the activities of the Network are organised.

From many years to now We are trying to convince our University and governmental authorities together with our traditional sponsors from ICTP and IPPS for the creation in Senegal of regional African Centre in Optics and Photonics with all the modern research and training facilities, for the benefit of all Africa.

From new perspectives in Africa, one can expect that new frontiers in the collaborative actions of the Network will be opened. Namely, one can expect the support of African Governments, for the establishment of hard laser infrastructure in the different nodal points of LAM Network. We are expecting also new partnership within the Project like Laser Lab Europe in collaboration and together with ALC

Acknowledgement

We would like to thank the Addus Salam International Centre for Theoretical Physics and the International Program in Physical Sciences at Uppsala University for there constant financial support and Scientific Collaboration. Our Thanks also to

Governmental and universities authorities of African countries in which the activities of the Network were organised.

THANK YOU FOR YOUR ATTENTION