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Narcotic Drug Detection and Identification through Synchronous Fluorescence Technique

Shalini Mittal*, Kiranmala Laishram, Saurabh Inamdar, N.R. Das, and A.K. Razdan

DRDO-Laser Science and Technology Centre, Delhi - 110 054, India
**E-mail: shalinimittal@lastec.drdo.in*

ABSTRACT

Illegal production of potentially hazardous narcotics as well as various psychotropic drugs is being carried out in the neighbouring countries and international market which is causing narco-terrorism a global havoc. Compared with traditional/natural drugs the synthetic drugs are more smuggled nowadays. Because of the vulnerability of the borders to drug trafficking, India has increased surveillance at borders and coasts and thus has tackled the problem to some extent. Authors developing a Narcotic drug sensor (point sensor) for detection and identification of Narcotic drugs based on Laser Induced Fluorescence more specifically Synchronous Fluorescence Spectroscopy in an effort. Some narcotic samples viz. Caffeine, Quinine and Tramadol were considered for the study. The fluorescence spectrum was studied using our own laboratory-based sensor incorporating charge coupled device-based Spectrometer and Laser source (266 nm wavelength) and commercial system from 'Horiba Scientific' incorporating Photomultiplier tube and Xe lamp source.

Keywords: Narcotic; Laser induced fluorescence; Synchronous fluorescence Spectroscopy; Excitation-emission matrix; EEM; Artificial intelligence; Artificial neural network; Charge coupled device; Ultraviolet; Convolutional neural networks

1. INTRODUCTION

Narcotics create addiction when swallowed by mouth or injected into the human body, they reduce the one's perception of pain and induce a feeling of exaggerated and unrealistic well-being which is known as 'euphoria'. The regular intake of narcotics produces their deadly effect since the body builds a tolerance to them such that even greater doses are required to achieve the same effect of euphoria. In today's world almost every country is affected directly or indirectly by terrorism. Trafficking/smuggling of narcotic drugs has direct and very intense connection to terrorism (Narco-terrorism). Early detection of drug will automatically lead to prevention of crime, corruption, terrorism and violent extremism in the country. Hence the development of rapid, sensitive and reliable methods for detection of drugs is of prime importance for every country. The technology must eliminate false positive results and reduce false negative ones, so that only the guilty person is being punished.

Laser Induced Fluorescence (LIF) is a robust and rapid technique over conventional method viz. reagent based colour kits for detection of narcotics due to its higher sensitivity without loss of precision. The Synchronous Fluorescence Spectroscopy (SFS) is a technique where the excitation and emission spectra of the organic aromatic compounds (specifically polycyclic aromatic hydrocarbons) are scanned simultaneously. It is the most promising technique for identification of narcotics because of its high selectivity. Here instead of single excitation wavelength as in LIF the sample is excited by a range of UV wavelengths and the corresponding fluorescence is observed over a range of emission wavelengths thus giving excitation-emission matrix (EEM).

With the EEM, 2D and 3D fluorescence maps of the test sample are formed, which provide the total relevant fluorescence spectral information (spectral signature), including both the absorption and the emission spectral signature of a specific chemical compound, and is termed the "total luminescence spectrum". Correlating data-base spectra and the sample spectra provide accurate identification and quantification of the unknown analyte. Although Raman spectroscopy also is used for detection of narcotics, a major problem for Raman measurements is that high level of fluorescence (intrinsic or caused by impurities) background makes it impossible to detect the weak Raman bands, thus giving low sensitivity. The plastic and glass packaging also exhibit Raman scattering[6,7] making it difficult for Raman technique to give selectivity at low concentrations of sample. Moreover both the liquid and solid samples must be free from dust particles.

Since the chemical selectivity of SFS is more than conventional other fluorimetric techniques, therefore the mixtures which have overlapping spectra of components can be analysed with the help of multi-component analytical method.

2. MATERIALS AND METHODS

Some narcotic samples viz. Caffeine, Quinine and Tramadol were considered for their fluorescence signature study. Caffeine, a natural stimulant affect the nervous system

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and along with ephedrine might cause too much stimulation and sometimes heart problems. Quinine may produce neurological complications, including altered mental status and coma. India is the origin of Tramadol, which is a synthetic drug (opiate), and the conventional detection kits used by Indian drug control agencies cannot detect it.

Narcotic molecules were excited through Laser and Xe-lamp source with liquid samples filled in quartz cuvette and powder samples in quartz customised cells using Fluorescence Spectrometer (Horiba PTI Quanta Master). Emission spectra were scanned to obtain measurable fluorescence intensity from pure narcotic chemicals and their mixtures with λ_{exc} ranging from 250 nm - 350 nm. The fluorescence spectrum was detected using CCD based Spectrometer with Laser source and Photomultiplier tube with Xe lamp source as shown in Fig. 1.

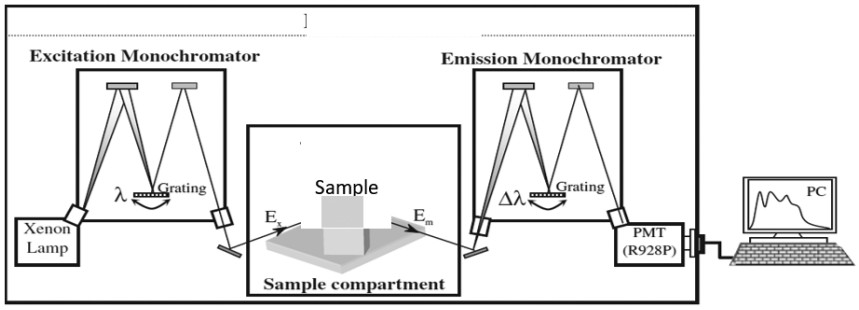

Figure 1. Schematic of the experimental instrumentation for SFS.

3. RESULTS AND DISCUSSIONS

The laser induced fluorescence (LIF) spectra were observed through various experiments done with laboratory-based sensor using 266nm laser source. Figure 2(a) shows the spectra of emission peak of tramadol at 298nm which is in good agreement with that quoted in the literature[1]. The peak locations for quinine obtained from experiments varied slightly from that reported i.e. 435 nm, 450 nm and 455 nm in literature[2,3].

Fluorescence lifetime and SFS spectra obtained using Horiba PTI Quanta Master (based on the technique called Time-Correlated Single Photon Counting (TCSPC) for Time-Resolved Fluorescence).

The excitation at 312 nm (λ_{exc}) from Xe lamp source given to caffeine powder and liquid sample, the emission peak λ_{em} occurred at 379 nm from liquid sample whereas that was 375 nm for caffeine powder, both of which are in good proximity with the value viz. 377 nm quoted in the literature[4-6].

The 3D spectral signature of drugs obtained by doing numerical analysis with the help of Origin software to filter the noise and interpolate the 3D diagrams to extended range of emission and excitation wavelengths. Even a small quantity up-to few part per million of narcotic sample can be detected and identified.

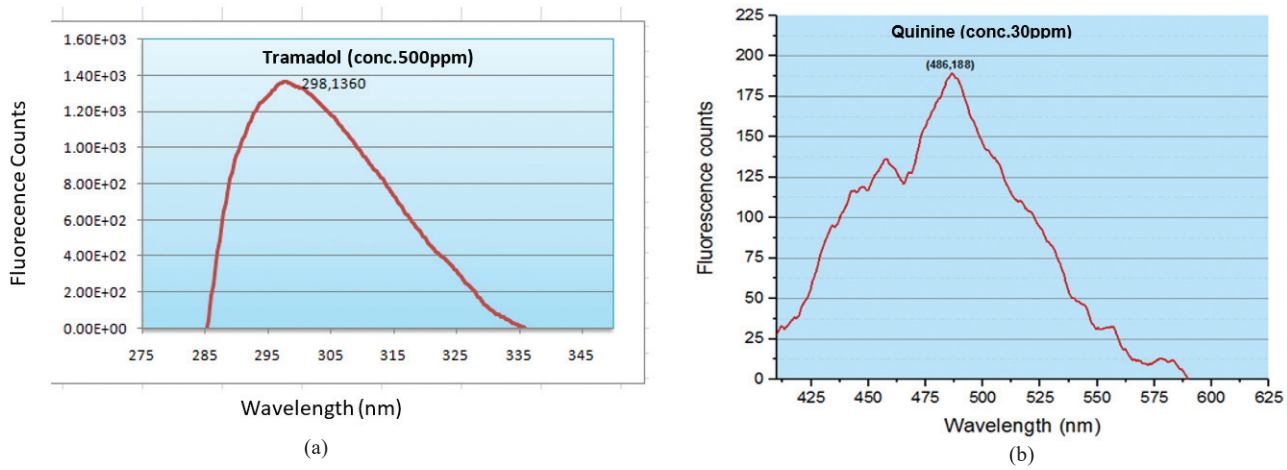

Figure 2. Spectrum of (a) Tramadol and (b) Quinine observed with 266nm Laser source using Lab based sensor.

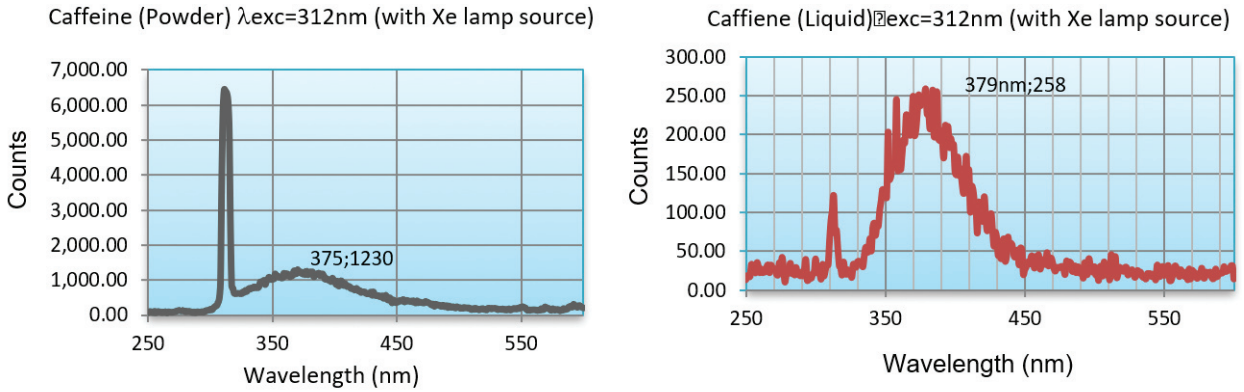

Figure 3. Emission spectrum of Caffeine.

The effects of different excitation wavelengths on the measured spectral shapes for various narcotic drugs are used for their identification through Artificial intelligence software (in NI Lab view with MATLAB script) indigenously developed at LASTEC. It is based on neural network algorithm which classifies data within ~17s based on statistical information extracted from patterns. The identification time was minimised by optimising the batch size and bias learn rate factor. Hundreds of 3D fluorescence patterns were used as input data in order to train the network. Convolutional neural networks (CNNs) classify spectral images based on their total fluorescence spectrum. More specifically, the architecture of the classifier contains several layers with weights. These layers are termed as the input layer, the convolutional layer, the max pooling layer, the softmax layer, the fully connected layer, and the output layer. These layers are implemented on each spectral signature to discriminate them against others. Figure 4 shows the SFS 3D spectrum of Caffeine, Quinine and Tramadol.

The results when running CNN algorithm on above samples fluorescence spectra is as shown in Fig. 5 below indicating Drug Name and Percentage Accuracy of identification of each sample along with the respective 3D fluorescence spectra.

4. CONCLUSION

The experimental outcomes viz. emission wavelengths of various samples are in good agreement with those quoted in the literature. The SFS technique can discriminate between similar samples by their spectral fingerprint. The effects of different excitation wavelengths on the measured spectral shapes (fluorescence) for various narcotic drugs were studied and used for their identification through CNN algorithm in software. The Fluorescence lifetime for various samples were also observed which was of the order of few nanoseconds.

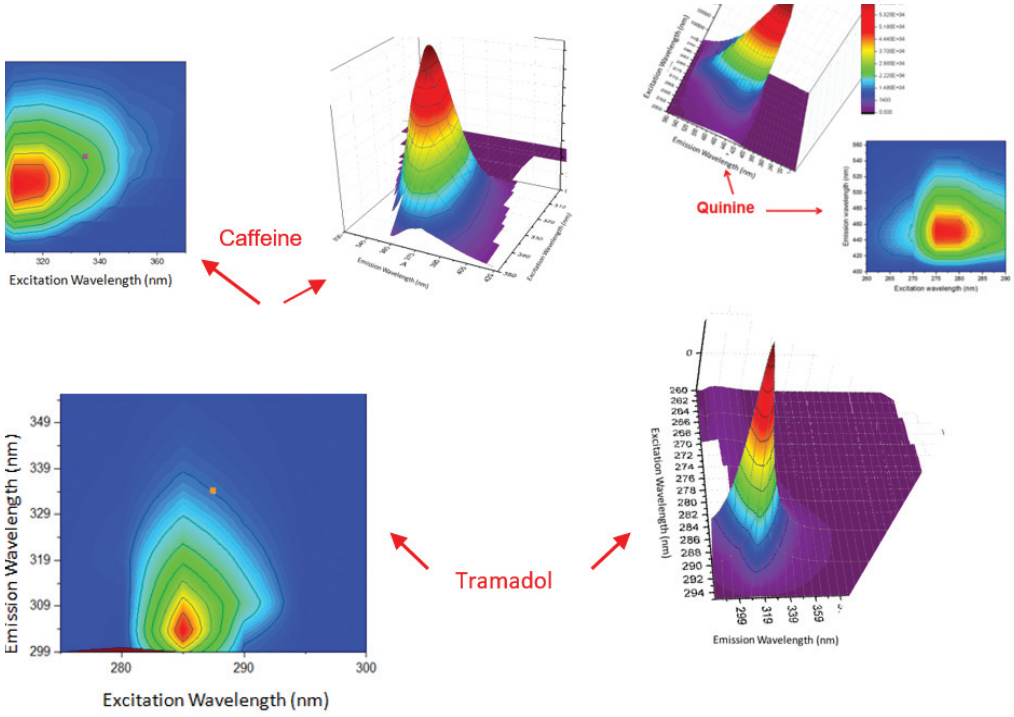

Figure 4. SFS 3D spectrum of Caffeine, Quinine and Tramadol.

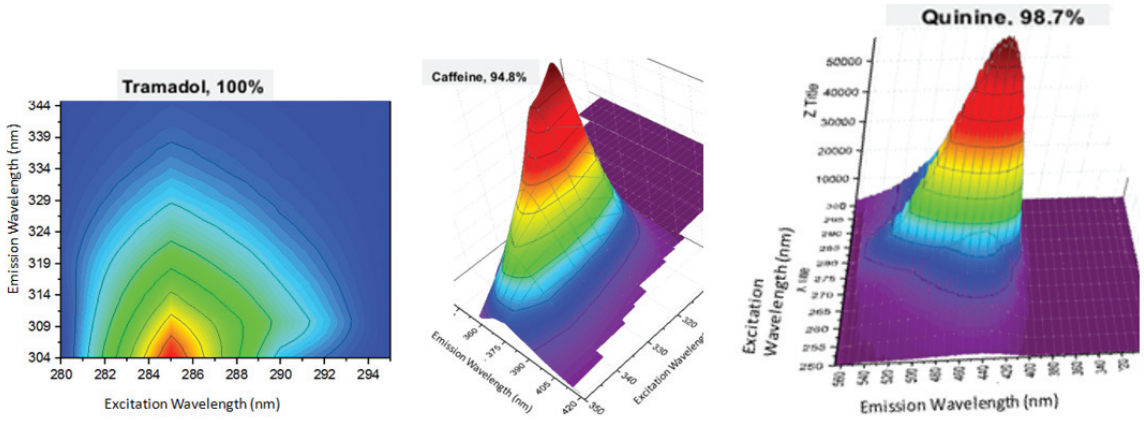

Figure 5. ANN software algorithm results identifying spectrum of Tramadol, Caffeine and Quinine.

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CONTRIBUTORS

Ms Shalini Mittal received his MTech (Electronics Engineering) from University of Allahabad, 2002, Presently working as Scientist 'D' at DRDO-Laser Science and Technology Centre, Delhi. She has worked in the area of development of antenna system, data acquisition system for high power laser systems and currently working in the area of Artificial Intelligence & Spectroscopy for Narcotic sensor development.
In the current study, she conceived the concept and carried out the complete experimental work. She has done rigorous studies on Narcotics fluorescence, developed their identification algorithm through SFS and realised it in NI Labview software by incorporating deep learning through MATLAB script.

Ms Kiranmala Laishram is MSc (Physical Chemistry) from Manipur University in 2002. She is working as Scientist 'E' at DRDO-Laser Science and Technology Centre, Delhi. She had been working in the area of laser materials, more specifically, nanopowder synthesis by wet chemical methods and material characterisation. Presently her area of interests are development of point sensors for Narcotic Drugs and Psychotropic Substances and toxic chemical detection by LIDAR technique.
In the current study, She has been instrumental in experimental work and procurement of drugs/chemicals.

Mr Saurabh Inamdar is MTech from IIT Delhi, is working as Scientist 'E' at DRDO-Laser Science and Technology Centre, Delhi. He had been working in the area of Matlab based analysis and simulation for fluorescence based systems.
In the current study, he is helpful in doing experimental work.

Dr N.R. Das received his PhD from Jamia Millia Islamia and MTech from IIT Kanpur. Currently working as Scientist F at DRDO-Laser Science and Technology Centre, Delhi. He has been working in the area of High power laser development and its effects on various composite materials. At present, he is working on the Development of various optical sensors for detection and identification of bio/chemical agents and Narcotics drugs.
In the current study, he has supported in doing experimental work at Delhi University, reviewed the incremental work, monitored the progress and pursued for various facilities in laboratory.

Dr Anil Kumar Razdan, obtained his MSc (Physics) and PhD in the area of Laser Spectroscopy from Indian Institute of Technology, Delhi. Presently working as Scientist G, at DRDO-Laser Science and Technology Centre, Delhi. His area of research interest include development of laser spectroscopy based sensors for remote sensing applications, development of high power laser systems, diagnostic techniques and adaptive optics.
In the current study, he pursued to initiate the development of narcotic sensor, supported in removing the hurdles, reviewed the work, monitored the progress.