Control Automation of Amplified Spontaneous Emission Measurement

Naqeeb Ahmed[1], Dr Ding Lu[2], Dr Matthew Chua[2]

[1] Department of Electronics and Communication Engineering, Guru Gobind Singh Indraprastha University
[2] Institute of Materials Research and Engineering, A*STAR

Abstract- Understanding the behaviour of organic semiconductor materials in laser applications hinges on discerning phenomena such as Spontaneous and Stimulated Emission. Amplified Spontaneous Emission (ASE) stands out as a pivotal indicator of their suitability. ASE, the mechanism through which lasers amplify light, underscores the material's potential for such applications. However, conducting ASE experiments traditionally demands significant time and manual effort.

This abstract introduces an automated setup designed to streamline the ASE experimentation process. By integrating Python, our setup reduces manual intervention and significantly accelerates experimentation. Leveraging this automated platform, researchers can swiftly evaluate the ASE characteristics of organic semiconductor materials, expediting the assessment of their suitability for laser applications. This innovation not only enhances efficiency but also facilitates a more comprehensive exploration of organic semiconductor materials' laser properties, promising advancements in laser technology.

I. INTRODUCTION

IN the realm of laser technology, the evaluation of organic semiconductor materials for laser applications hinges on a comprehensive understanding of fundamental optical processes. Spontaneous and Stimulated Emission, intrinsic to the behavior of these materials, play pivotal roles in determining their suitability. Among these phenomena, Amplified Spontaneous Emission (ASE) emerges as a reliable indicator of the potential of organic semiconductors to function as effective laser mediums.

The process of ASE is intricately linked to the interplay of three crucial optical transitions: Population Inversion, Spontaneous Emission, and Stimulated Emission. Initiated by the absorption of energy from an excitation source, typically a pump laser, Population Inversion sets the stage by ensuring an abundance of excited states relative to ground states within the material. Subsequently, excited states undergo Spontaneous Emission, releasing photons as they transition back to lower energy levels. This emission is followed by Stimulated Emission, where a photon triggers the relaxation of another excited state, yielding identical photons that propagate coherently.

The culmination of these transitions manifests as ASE, wherein a cascade of identical photons is amplified within the material. This amplification, akin to a 'snowball' effect, underscores the essence of laser operation, where the coherent emission of light is quintessential.

To assess ASE and ascertain the suitability of organic semiconductor materials for laser applications, precise measurement methodologies are imperative. Central to this endeavor is the concept of fluence, representing the energy delivered per unit area from a radiating source. Accurate determination of fluence is crucial as it provides a comprehensive measure of excitation energy, particularly essential when evaluating materials with varying spot sizes of excitation sources.

This introduction sets the stage for understanding the measurement of ASE, elucidating the experimental setup involving laser excitation of organic films and subsequent collection of ASE emission via optical spectrometry. The critical role of pump fluence in driving ASE is underscored, with emphasis placed on identifying the ASE threshold, a key parameter indicative of a material's potential as a laser gain medium.

In light of these foundational concepts, this study aims to delve deeper into the characterization of ASE in organic semiconductor materials, paving the way for advancements in laser technology

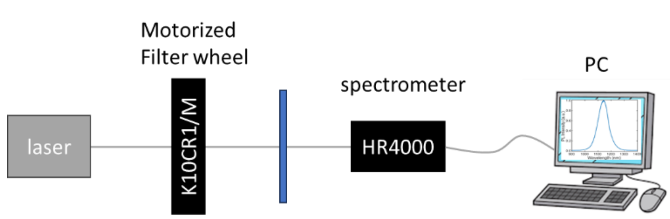

Figure 1 : Setup Schematics

II. PYTHON

Python, a versatile and widely-used programming language, plays a pivotal role in automating the experimental setup and analyzing the data obtained from the Amplified Spontaneous Emission (ASE) experiment. Known for its simplicity, readability, and extensive library support, Python offers a robust platform for scientific computing and data analysis tasks.

A. Significance of Python in Automation:

Python's rich ecosystem of libraries and tools facilitates automation in various scientific domains, including optics and materials science. In the context of the ASE experiment, Python enables the seamless integration of hardware control, data acquisition, and analysis, streamlining the experimental workflow and minimizing manual intervention.

B. Python Libraries Used

1. Seabreeze

Seabreeze is a Python library designed for controlling Ocean Optics spectrometers, facilitating the acquisition of spectral data with ease and flexibility. Leveraging Seabreeze, researchers can interface with Ocean Optics spectrometers seamlessly, enabling the capture of spectra across a wide range of wavelengths. This library provides functionalities for initializing spectrometers, configuring acquisition parameters, and retrieving spectral data, allowing for precise characterization of the amplified spontaneous emission (ASE) spectra in the experiment. By utilizing Seabreeze, researchers can efficiently integrate Ocean Optics spectrometers into their experimental setups, enabling real-time monitoring and analysis of spectral intensity profiles.

2. PyWin32

PyWin32 is a Python library that provides access to the Windows API, enabling interaction with various system-level functionalities and external devices. In the context of the ASE experiment, PyWin32 is utilized for interfacing with the StarBright power meter, a crucial component for measuring the power output of the laser source. By leveraging PyWin32, researchers can communicate with the StarBright power meter, retrieve power measurements, and monitor the stability of the laser output during the experiment. This library offers a convenient and reliable interface for acquiring real-time power data, facilitating accurate calibration and optimization of the experimental setup.

3. Direct DLL Calls for Thorlabs ND Filter

In certain experimental setups, direct DLL (Dynamic Link Library) calls may be employed to interface with external devices, such as the Thorlabs ND (Neutral Density) filter wheel. By directly calling the DLLs provided by Thorlabs, researchers can control the movement of the ND filter wheel programmatically, adjusting the optical attenuation of the laser beam with precision. This approach offers a low-level interface for manipulating the ND filter wheel, bypassing the need for proprietary software or complex communication protocols. Through direct DLL calls, researchers can incorporate Thorlabs ND filters seamlessly into their experimental setups, enabling dynamic control of laser intensity and facilitating the optimization of ASE measurements.

4. Matplotlib

Matplotlib is a comprehensive library for creating static, animated, and interactive visualizations in Python. In the ASE experiment, Matplotlib is instrumental for visualizing spectral data, power measurements, and other experimental parameters. Researchers can utilize Matplotlib to generate plots, charts, and graphs that illustrate the ASE spectra, intensity profiles, and trends over time. Additionally, Matplotlib enables the customization of plot aesthetics, annotations, and labels, enhancing the clarity and interpretability of experimental results.

5. Tkinter

Tkinter is the standard GUI (Graphical User Interface) toolkit for Python, providing a convenient framework for creating desktop applications with interactive user interfaces. In the ASE experiment, Tkinter is utilized to develop a live GUI for real-time monitoring and control of the experimental setup. Researchers can design custom widgets, buttons, and interactive elements using Tkinter, allowing for intuitive control of spectrometer parameters, laser power settings, and data acquisition processes. The live GUI enhances the user experience, enabling researchers to visualize experimental data in real-time and make dynamic adjustments to the experiment parameters.

III. PROGRAM FLOW

The program flow of the ASE (Amplified Spontaneous Emission) experiment setup is structured to automate data acquisition, control experimental parameters, and visualize real-time results. This section delineates the interactions between the Python scripts involved in orchestrating the ASE experiment. The ASE experiment is facilitated through the collaboration of four Python scripts.

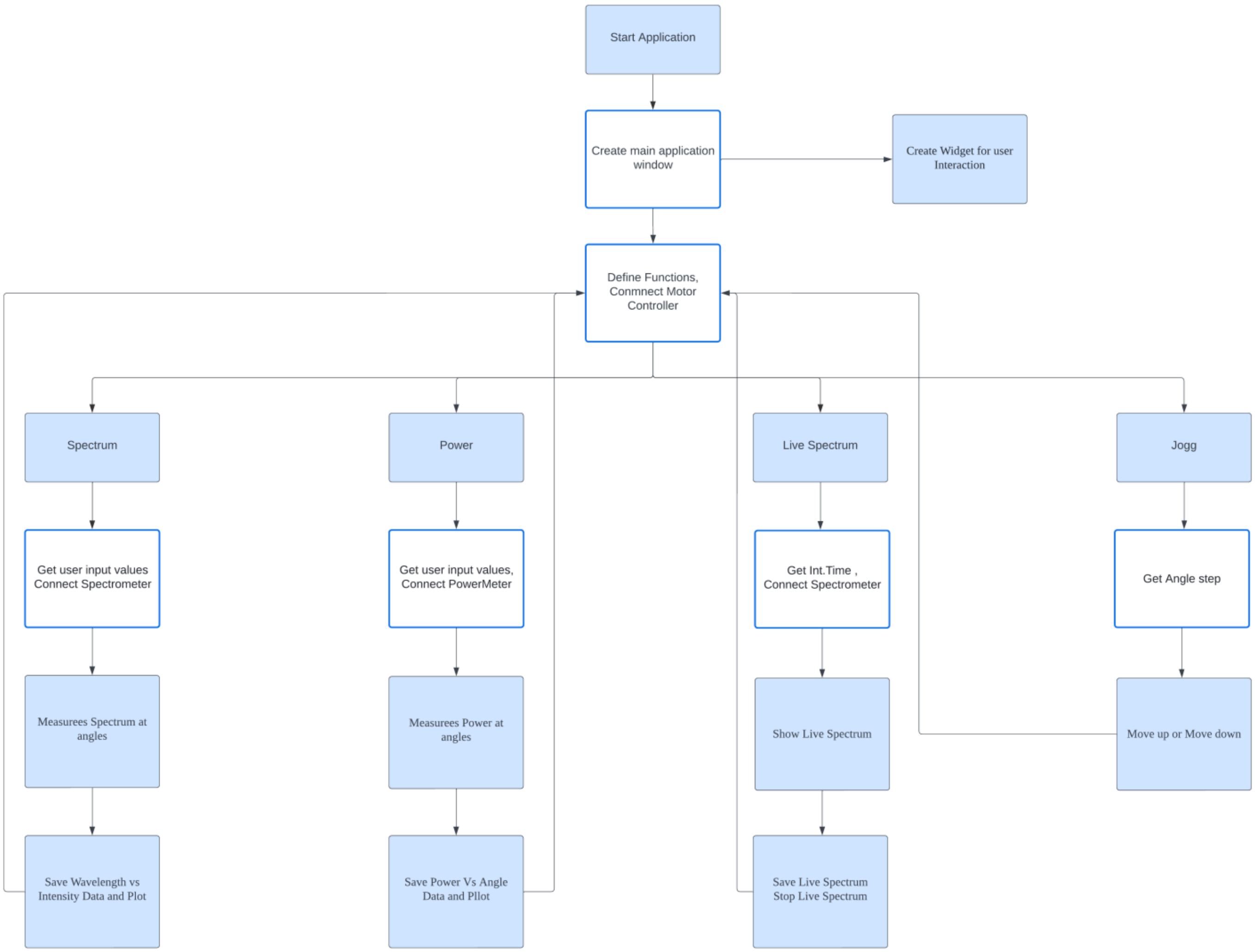

Figure 2 Program Flow

A. *app.py*

1. **Functionality**: Initializes the graphical user interface (GUI) using Tkinter, facilitating user interaction and data visualization.
2. **Log Files:** Creates log files to record experimental parameters, measurements, and exceptions encountered during execution.
3. **Integration**: Calls functions and classes from other Python scripts to coordinate the ASE experiment.

B. *main.py*

1. **Main Logic**: Contains the primary control flow and logic of the ASE experiment.
2. **Class Instantiation**:.
   i. Motor Controller: Controls the Thorlabs ND filter wheel to adjust optical attenuation.
   ii. Spectrometer: Manages spectral data acquisition using Ocean Optics spectrometers.
   iii. Measurement: Coordinates step-by-step data collection, including movement of the ND filter wheel and spectral acquisition.
   iv. Power Meter: Interfaces with the power meter for concurrent power measurements.

C. LiveSpectum.py

1. **Live Plotting**: Implements real-time visualization of spectral data through dynamic plots.
2. **Matplotlib Integration**: Utilizes Matplotlib for creating and updating live spectrum plots within the GUI.
3. **GUI Integration**: Interacts with the GUI created in app.py to display live spectrum plots.

D. Sensor.py

1. **Power Meter** Interface: Defines the Sensor class to handle communication with the power meter.
2. **Functionality**: Implements methods for initializing the power meter, querying power measurements, and managing communication protocols.
3. **Integration**: Enables concurrent power measurements alongside spectral data acquisition in main.py.

The overall execution flow of the ASE (Amplified Spontaneous Emission) experiment setup follows a systematic progression to automate data acquisition, control experimental parameters, and visualize real-time results. The process begins with the initialization stage, where execution is initiated through app.py. This script initializes the graphical user interface (GUI) and log files, setting the groundwork for subsequent operations. Users then interact with the GUI to initiate the ASE experiment, providing input parameters and initiating data collection. Under the coordination of main.py, the experiment control phase commences, with the movement of the ND filter wheel and spectral data acquisition being orchestrated seamlessly. Concurrently, power measurements are collected alongside spectral data acquisition, facilitated by sensor.py. As data is acquired, livespectrum.py updates the live spectrum plot within the GUI, providing real-time visualization of spectral data trends. Throughout the experiment, app.py diligently logs relevant information, ensuring comprehensive analysis and record-keeping for future reference and analysis. This structured execution flow ensures efficient automation, precise data acquisition, and intuitive visualization within a user-friendly interface, facilitating seamless experimentation and analysis in the ASE domain.

IV. HOW TO USE APPLICATION (FUNCTIONS)

Before delving into the specific functionalities, here's a brief overview of all functions available in the program:
User can adjust the ND filter position using jog or move-to options. The program also allows viewing real-time spectral data with the live spectrum plot feature. Additionally, users can collect spectral data at specified angles through the integration of the ND filter and spectrometer. Moreover, the program enables measuring power at different ND filter angles using the power meter.

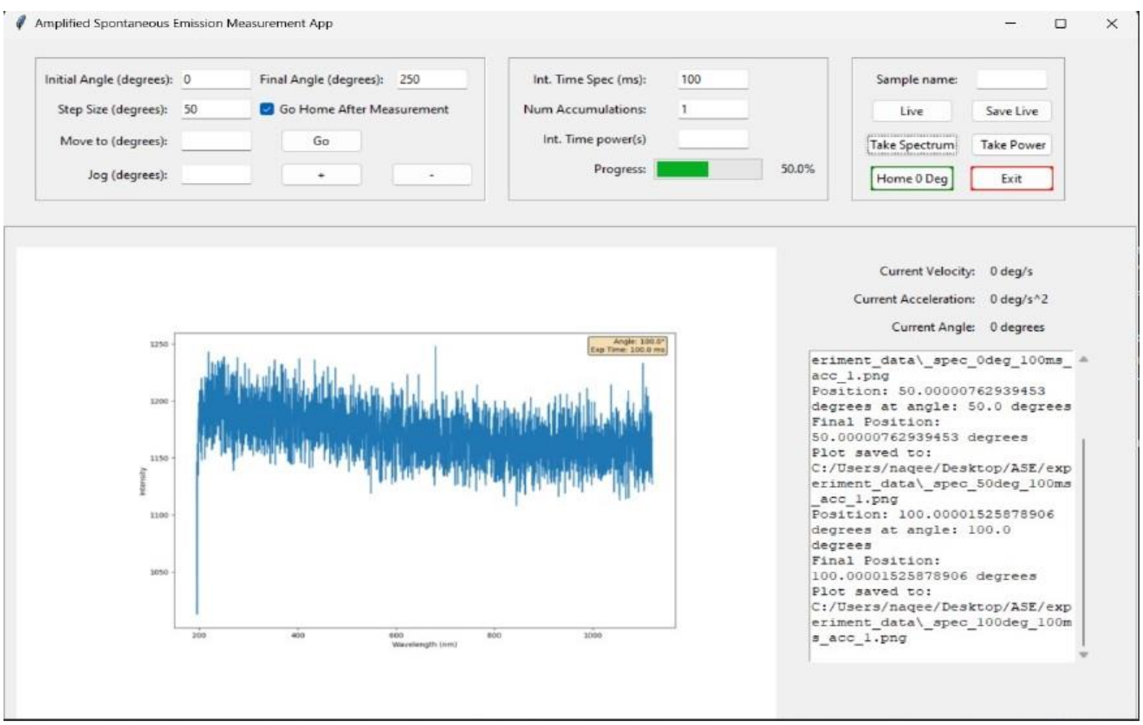

Figure 3 GUI

A. Functionality with ND Filter:

Users can effectively control the position of the ND filter using two primary methods:

1. **Jog Functionality**: With the jog functionality, users can navigate the ND filter incrementally. To utilize this feature, input the desired jog size, specifying the magnitude of the movement. Then, indicate the direction of movement by entering **"+"** for a positive jog or **"-"** for a negative jog. This allows for precise adjustments of the ND filter position in small increments.

2. **Move To Option**: Alternatively, users can directly specify the exact angle they wish to move the ND filter to using the "Move To" option. By inputting the desired angle, the program will swiftly adjust the ND filter to the specified position, providing users with the flexibility to navigate to specific angles with ease and accuracy.

B. Functionality with Spectrometer:

Users can utilize the spectrometer functionality to visualize real-time spectral data and save it for future analysis. Here's a detailed breakdown of the process:

1. **Live Spectrum Visualization**:
   - Input Integration Time: Before initiating live spectrum visualization, users can specify the integration time for the spectrometer. This parameter determines the duration over which spectral data will be collected at each wavelength point.
   - Click "Live" Button: Once the integration time is set, users can initiate the live spectrum visualization by clicking the "Live" button. This action triggers the spectrometer to start collecting spectral data in real-time.
   - Real-time Data Display: As the spectrometer collects data, the live spectrum plot is dynamically updated in the GUI, allowing users to observe changes in spectral intensity across different wavelengths instantaneously.

2. **Save Live Spectrum**:
   - Remove Background Noise: To ensure accurate analysis of the live spectrum, users can employ the "Save Live" option, which also serves to remove background noise from the data.
   - Save for Later Analysis: By clicking the "Save Live" button, users can store the live spectrum data for later analysis. This feature enables users to preserve important spectral information and facilitates detailed examination and comparison of spectral data sets over time.

C. ND Filter and Spectrometer Integration:

Users can seamlessly integrate the ND filter with the spectrometer to collect spectral data at specified angles. Here's a detailed overview of the integration process:

1. **Input Sample Details**:
   - **Provide Sample Name**: Begin by inputting the name of the sample being analyzed. This information serves as a reference for organizing and categorizing collected data.
   - **Specify Initial and Final Angles**: Define the starting and ending angles for the ND filter movement. These angles determine the range over which spectral data will be collected.
   - Input the **integration time** for the spectrometer and the **number of accumulations** to ensure accurate data acquisition.

2. **Define Step Size**:
   - Set Step Size: Specify the step size, which determines the increment by which the ND filter will move from one angle to the next. This parameter governs the granularity of data collection and can be adjusted based on experimental requirements.

3. **Initiate Data Collection**:
   - Press "**Take Spectrum**": After inputting the sample details and defining the step size, initiate the data collection process by clicking the "Take Spectrum" button. This action prompts the system to begin acquiring spectral data at each specified angle.

4. **Data Acquisition Process**:
   - Sequential Angle Movement: The ND filter will systematically traverse from the initial angle to the final angle in sequential steps, as dictated by the specified step size. For instance, if the initial angle is 0 and the final angle is 10 with a step size of 5, data will be collected at angles 0, 5, and 10.
   - Spectral Data Acquisition: At each specified angle, the spectrometer will initiate data collection, capturing spectral data according to the predefined integration time and number of accumulations. This meticulous process ensures the acquisition of precise and reliable spectral intensity measurements across the desired wavelength range.

5. **Display and Save Data**:
   - Wavelength vs. Intensity Plot: As spectral data is acquired, the wavelength vs. intensity plot will be dynamically updated and displayed in the GUI. This plot provides a visual representation of spectral characteristics at each angle.
   - Continuous Data Saving: The collected spectral data is continuously saved in the background, ensuring that no data is lost during the experiment. This enables users to access and analyze the collected data at their convenience for further interpretation and analysis.

D. ND Filter and Power Meter Integration:

To seamlessly integrate the ND filter with the power meter for comprehensive data collection, follow these steps:

1. **Enter Sample Details**:
   - **Provide Sample Name**: Input the name of the sample under analysis. This designation helps organize and categorize collected data for easy reference during analysis.
   - **Specify Initial and Final Angles**: Define the starting and ending angles for the ND filter movement. These angles determine the range over which power measurements will be conducted. Additionally, specify the step size to dictate the increment by which the ND filter will move between angles.

2. **Set Integration Time for Power Meter**:
   - Ideally, set the integration time for the power meter to 0.05. This parameter determines the duration over which power measurements will be averaged, ensuring accurate and stable readings.

3. **Initiate Power Measurements**:
   - Click **"Take Power**" to initiate power measurements. This action prompts the system to begin collecting power data at each specified angle.
   - At each angle, the power meter will pause and record power data, correlating each measurement with the corresponding angle of the ND filter.

4. **Data Presentation and Saving**:
   - After data collection is complete, a plot displaying all angles with their corresponding power values will be generated in the GUI. This visual representation enables users to interpret power variations across different ND filter angles.
   - The collected data is continuously saved in the background, ensuring that no information is lost. This facilitates future analysis and comparison of power measurements for comprehensive understanding and evaluation of the experimental setup.

REQUIRED DRIVER AND LIBRARY LINKS

[1] Download and install the Kinesis software from Thorlabs Software.
[2] Download and install Spectra Suite for Ocean Optics spectrometers.
[3] Download and install StarLab for Starbright Power Meter.
[4] Learn about ThorLabs Kiness DLL
[5] Learn about Python-Seabreeze
[6] Learn about Starlab Power Meter
[7] Find the Complete code GitHub repository.

AUTHORS

First Author – Naqeeb Ahmed, naqeeb2710@gmail.com.
Second Author – Ding Lu, dingl@imre.a-star.edu.sg.
Third Author – Matthew Chua, matthew_chua@imre.a-star.edu.sg