High Power CW Laser-induced Thermal Effects on an Electronic Device

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Abstract—Unmanned aerial vehicles (UAVs) have been considered for different military and civilian applications due to their wide range of functionalities. The most important component of an UAV is the flight computer and the associated electronics. High-energy laser systems used for counter-drone technology can induce faults in the electronic circuits, which depend on many parameters including the circuit technology and the laser characteristics. High-power laser-induced thermal effects can be vulnerable to different electronic components and therefore the performance of the electronic devices. In this study, thermal effects on the performance of a Raspberry pi are investigated.

Keywords-Raspberry pi; Laser-induced thermal effects; Data acquisition; Counter-drone technology; UAV

I. INTRODUCTION

Unmanned aerial vehicles (UAVs) are widely used for military and civilian applications including real-time monitoring, providing wireless coverage, remote sensing, search and rescue, delivery of goods, security and surveillance, precision agriculture, and civil infrastructure inspection [1]. To counter the performance of the UAVs, several counter-drone technologies such as radio frequency jammers, global positioning system (GPS) spoofers, high power microwave (HPM) devices, nets and guns, high-energy lasers, etc. have been developed. An UAV is a complex system composed of several sub-modules, such as the UAV airframe, the flight computer, the payload, the mission/payload controller, the base station, and the communication infrastructure [2]. The heart of the UAV is the flight computer and associated electronics, which are vulnerable to the directed energy systems. Directed energy systems composed of high-energy lasers can destroy UAVs by heating, melting, burning, and/or evaporation. Electronic components can also be damaged/neutralized due to overheating without experiencing even melting. In this paper, a Raspberry Pi is considered as an equipment under test (EUT), which is irradiated by a high-power continuous wave (CW) laser, and its performances such as central processing unit (CPU) temperature, random-access memory (RAM) usage, CPU clock frequency, and CPU load are actively monitored. The CPU temperature was primarily considered to observe the thermal effects induced in EUT. Components of the EUT is globally heated by the laser beam and the EUT performances are evaluated.

II. EXPERIMENT

A CW infrared fiber laser coupled to a short-range telescope as shown in Fig. 1(a) was used. The EUT along with its cover as shown in Fig. 1(b) was placed in an experimental chamber. The front surface of the EUT cover was exposed to the laser beam operating at 10% of its maximum power (6 kW). The beam diameter was kept sufficiently large to irradiate a wide area of the EUT and to avoid melting of the EUT cover. An external SSD storage device was used to save the data.

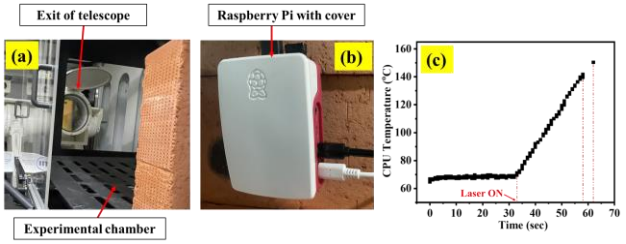

Fig. 1 (a)-(b) Experimental apparatus. (c) CPU temperature with time before and after laser irradiation.

III. DISCUSSION

The CPU temperature, RAM usage, CPU clock frequency, and CPU load were actively monitored at different times before and after the laser irradiation. The CPU temperature is found to increase after the start of the laser irradiation as shown in Fig. 1 (c). At higher CPU temperatures, the data acquisition rate was found to be decreased. At about 141° C, EUT stopped saving the data and was shut down at about 150° C. Further investigation will be made by irradiating the laser beam locally on individual electronic components of the EUT to identify its most vulnerable element. This study can be extended to other electronic devices and will be helpful to design an appropriate protective case for electronic devices that can prevent laser-induced thermal effects. Furthermore, this will also provide information about the required laser power level to induce desired thermal effects to neutralize the electronics of UAVs involved in malicious activities.

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