**Project Title**  
**Ground-Based Laser Power Transfer for Autonomous Drone Energy Harvesting Using Adaptive Control**

**Introduction**  
This project focuses on the development of an autonomous energy transfer system where a ground-based turret uses a high-intensity laser to recharge a drone’s battery. The drone, equipped with a Light Dependent Resistor (LDR), harvests energy when illuminated by the laser. A combination of sensors, including MPU6050, BMP581, GPS, and ESP32, ensures precise tracking and communication. The system adapts dynamically, activating when the drone's battery drops below 50%, with the laser alignment facilitated by PID control and PWM.

**Abstract**  
This project proposes a solution for autonomous drone power management using a ground-based laser power transfer system. The system consists of a high-intensity laser on the turret, which, when activated, targets the LDR on the drone for energy harvesting. Key technologies include **PID control**, **PWM for servo motor control**, and **ESP32 for communication**. The area increase of the LDR reduces its resistance and voltage drop, enhancing power transfer efficiency. Optics at the turret and drone receiver help optimize energy harvesting. These optimizations contribute to improved overall system efficiency and extended operational time for drones.

**Methodology**

1. **LDR Functionality & Area Optimization:**  
   The **LDR** on the drone plays a critical role in harvesting energy when illuminated by the laser. Increasing the surface area of the LDR reduces its resistance and voltage drop, improving the efficiency of energy generation. As the light intensity increases, the LDR generates more current, which contributes to faster battery recharge.

**Material of the LDR:**  
The LDR is typically made from **cadmium sulfide (CdS)**, a semiconductor material. When light of a specific wavelength falls on the LDR, photons are absorbed by the semiconductor, exciting electrons from the valence band to the conduction band. This generates free electrons that contribute to current flow, which can be used to charge the drone’s battery.

**Wavelength and Light Interaction:**  
The LDR is most responsive to specific wavelengths of light, generally in the **visible spectrum**. When light of these wavelengths strikes the LDR, it provides sufficient energy to excite electrons into the conduction band. This process generates electrical current, which is then used for energy harvesting. The efficiency of the LDR depends on the intensity of the incident light and its wavelength.

**Lifespan of LDR:**  
Much like solar panels, LDRs have a limited lifespan. Over time, the material can degrade due to prolonged exposure to light, especially at high intensities, which reduces their ability to generate electrical energy. The typical lifespan of an LDR is several years, after which its efficiency decreases significantly, similar to the degradation observed in solar panels.

1. **Adaptive Control & Sensors:**
   * **Barometric Sensor:** The **BMP581** barometric sensor measures pressure changes, which are used to calculate the drone’s altitude. This helps in stabilizing the drone and maintaining optimal alignment with the laser.
   * **MPU6050 Sensor:** The **MPU6050**, which integrates a 3-axis accelerometer and a 3-axis gyroscope, is responsible for tracking the drone’s orientation and stabilizing its flight path.
   * **GPS Module:** The **u-blox Neo 6M GPS** sensor module provides precise geographical coordinates, allowing the system to monitor the drone’s position and ensure proper laser alignment.
2. **PID Tuning and PWM Control:**  
   The turret uses two servo motors (for pan and tilt movements) to adjust the laser's alignment. **PID control** is used to fine-tune the servo positions, ensuring smooth, precise adjustments and minimizing alignment errors. The system uses **PWM** to control the servo motors, adjusting the laser beam's angle with high accuracy to ensure the laser consistently points at the LDR for effective energy harvesting.
3. **Optics Optimization:**
   * **Optics at the Ground-Based Turret:** The turret utilizes optics to focus and converge the laser beam, increasing its intensity and ensuring that it remains directed precisely at the drone’s receiver. This is crucial for maximizing the power transfer efficiency.
   * **Optics at the Drone Receiver:** The drone’s receiver uses optical lenses to focus the incoming laser light onto the LDR, optimizing the energy harvesting process. The optical setup ensures that as much of the laser energy as possible is captured, improving overall system efficiency.
4. **Microcontroller Role (ESP32):**  
   The **ESP32** serves as the communication link between the drone and the turret. It processes data from the drone's sensors and adjusts the laser's alignment accordingly. It also handles power transfer requests, activating the laser when necessary. By using the ESP32, real-time adjustments to PID parameters and laser tracking are made possible.

**Invention or Innovation**  
This project innovatively combines advanced control mechanisms, optics, and sensor technologies to develop a self-adjusting laser power transfer system. The adaptive control system, aided by optics to optimize laser intensity, ensures that the drone can continuously harvest energy without manual intervention, thereby increasing its operational autonomy.

**Outcome/Expected Outcome**  
The primary outcome is a fully autonomous drone system that recharges itself during flight using a high-intensity laser. Optimizations in LDR area, optics at the turret and receiver, and PID-controlled servo motors enhance energy harvesting efficiency. The system is expected to provide a continuous power supply to the drone, improving operational efficiency and reducing the need for manual recharging.

**Beneficiaries & Social Benefits of the Project**

* **Drone Industry:** The project can revolutionize drone operations by enabling longer flight times without the need for landing or manual recharging.
* **Energy Systems:** By utilizing efficient energy harvesting techniques, the project promotes sustainable energy practices, reducing reliance on conventional charging methods.
* **Defense and Aerospace:** Autonomous drone missions can be significantly extended, benefiting sectors like surveillance, search and rescue, and logistics.
* **Environmental Impact:** The use of renewable energy via laser power transfer reduces the environmental footprint of drone operations, promoting energy-efficient solutions.

**Conclusions**  
This project introduces a novel approach to autonomous drone energy harvesting using laser power transfer. By incorporating PID control, PWM for servo motor operation, LDR optimization, and optics at both the turret and drone receiver, the system achieves efficient energy harvesting. These innovations extend the drone’s operational time, improving the autonomy and sustainability of drone-based systems.

**References**

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**Circuit Connections**

