Laser Intrusion System

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Abstract

This project presents the design and development of a Laser Intrusion Detection System, a compact, low-cost, and efficient security setup used to detect unauthorized entry by breaking a laser beam. The system is implemented as a museum protection model, where a priceless artifact is safeguarded using multiple laser beams and light sensors. When an intruder crosses the laser grid, the Arduino Nano detects the interruption through LDR and infrared sensors and triggers an alarm. The project integrates both hardware and software automation, demonstrating real-world applications in museums, banks, and jewellery stores.

OBJECTIVE

The main objectives of this project are:

- To design a laser-based intrusion detection system using sensors and microcontrollers.
- To create a museum-style sun board model demonstrating real-world security usage.
- To implement a multi-zone laser grid with redundant detection for reliability.
- To develop an alert system triggered by laser and infrared interruption.

Components

Microcontrollers

- Arduino Nano – sensor control, alarm logic

Sensors and Modules

- LDRs (Light Dependent Resistors) – beam interruption detection
- Infrared Sensor
- Laser Diodes
- OLED Display – for user interface
- Buzzer – audible alert
- Red and Blue LEDs
- 330-ohm resistors

Power & Driver Circuit

- Lithium Polymer Battery giving 12v supply with 5200 Mah Power
- 5V DC-DC Step down converter
- NPN transistors

Mechanical Model

- Sun board Structure

WORKING PRINCIPLE

4.1 Laser + LDR Intrusion Detection

a) Each laser shines directly onto its corresponding LDR.

- Normal: Laser falls on LDR → low resistance → safe
- Intrusion: Laser blocked → LDR resistance rises → Arduino triggers buzzer + alarm LEDs

This creates a 2-point perimeter protection around the artifact.

b) IR Sensor Artifact Removal Detection

An IR reflective sensor is placed under the artifact.
When the artifact is present, IR reflection is strong.
If someone lifts the artifact:

- IR reflection drops
- Arduino detects the removal
- Immediately triggers 12V buzzer and red LEDs

This provides direct object theft detection.

c) OLED Display

Shows live system status:

SYSTEM ARMED

LASER1: OK

LASER2: OK

ARTIFACT: SAFE

On intrusion:

*** ALERT ***

LASER BREACH!

On artifact removal:

!!! ARTIFACT TAKEN!!!

d) Alarm System

- 12V buzzer is driven using a transistor or MOSFET
- Red LEDs flash during alert
- Blue LEDs stay ON as museum lighting (optional)

Software Logic

5.1 Overview

The system protects a museum artifact using two optical beams and an under-pedestal proximity sensor. Each laser projects a beam onto an LDR positioned opposite it. A separate IR reflectance sensor beneath the artifact detects removal. The Arduino Nano continuously monitors sensor readings; when any laser beam is interrupted or the IR sensor indicates the artifact has been lifted, the controller triggers the alarm chain (12V buzzer + red LEDs) and updates the OLED display.

5.2 Laser–LDR Beam Interruption Detection

Two laser diodes LASER1 and LASER2 are used to create two separate security beams inside the model. Each laser is aligned with an LDR placed directly opposite it.

Normal Condition

- Laser directly shines on LDR →
    - LDR1 gives a **high analog reading** (v1 > th1)
    - LDR2 gives a **low analog reading** (v2 < th2)
- Arduino marks both beams as **stable**.

Intrusion Condition

When an object or hand crosses the beam:

- LDR1: its value **drops below threshold th1**
- LDR2: its value **rises above threshold th2**

The code reads:

if (v1 < th1) → Beam 1 triggered

if (v2 > th2) → Beam 2 triggered

Once detected:

- The system immediately runs triggerAlarm()
- Red LEDs flash
- Blue LEDs turn OFF
- Buzzer outputs siren pattern
- OLED displays the specific breached beam (“Beam 1 Active” or “Beam 2 Break”)

This forms the PRIMARY INTRUSION DETECTION.

5.2 Artifact Removal Detection (IR Sensor)

An IR sensor is mounted underneath the artifact platform.

Working Logic

- When the artifact is present → the IR sensor receives reflected IR light → its digital output remains **LOW**.

- When the artifact is lifted → reflection disappears → sensor output becomes **HIGH**.

The code checks this condition:

if (irState == HIGH) triggerAlarm("Artifact Taken");

This is a **direct theft detection** independent of laser beams.
EVEN IF SOMEONE BYPASSES THE LASERS, LIFTING THE ARTIFACT WILL TRIGGER THE ALARM.

5.3 Alarm Activation Mechanism

Whenever any one of the three triggers occurs:

1. **Beam 1 interrupted**
2. **Beam 2 interrupted**
3. **Artifact removed**

The system immediately executes:

triggerAlarm(msg);

This function:

- Clears OLED and prints **"ALARM!"**
- Shows the cause (Beam 1, Beam 2, or Artifact)
- Turns OFF both blue LEDs
- Activates **alarmSiren()**, which:
    - Pulses buzzer ON/OFF
    - Flashes both red LEDs in sync
    - Repeats this for 6 cycles

A **cooldown period** prevents rapid reactivation:

if (millis() - lastAlarmTime < alarmCooldown) return:

This ensures the alarm plays fully once before it can trigger again.

5.4 Status Indication LEDs

The system uses 4 LEDs:

Blue LEDs (BLUE1, BLUE2)

- Always ON during normal monitoring
- Provide museum-lighting effect
- Turn OFF during alarm

Red LEDs (RED1, RED2)

- Stay OFF in normal state
- Flash rapidly during alarm as visual warning

- **Status LEDs for beams (STATUS1, STATUS2)**
- Turn ON only when the corresponding beam is broken
- Helps identify which beam failed physically inside the model

5.5 OLED Display Output

The OLED provides **live feedback**, replacing the need for a laptop or serial monitor.

Normal Mode Display

SYSTEM ARMED

Beam1: <value>

Beam2: <value>

Monitoring...

- Values update every cycle for real-time diagnostics.

Alarm Display

ALARM!

<message>

Message depends on the exact cause:

- "Artifact Taken"
- "Beam 1 Active"
- "Beam 2 Break"

After alarm, the display resets to monitoring mode once cooldown ends.

5.6 System Boot Sequence

At startup, the OLED runs a custom animation (hackerBoot()):

- Shows simulated system checks
- Plays short confirmation beeps
- Fills a progress bar
- Ends with a **READY** display

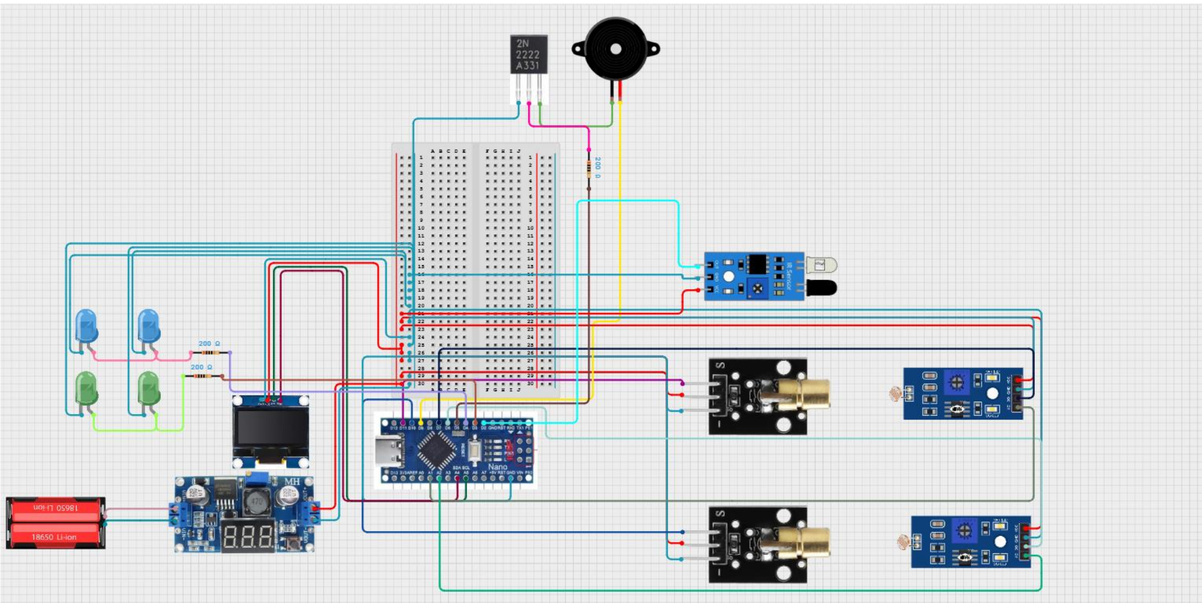
This improves presentation quality and signals that all modules were initialized.

5.7 Power System Working

- A **buck converter** drops the 12V supply to a stable **5V rail**.
- The custom PCB distributes 5V to:
  - Arduino Nano
  - OLED
  - LDR circuits

    - Blue/Red LEDs
    - IR sensor

- The **12V buzzer** is driven directly from the 12V line, activated via a digital pin.



Circuit diagram

Applications

This Laser–IR based intrusion system has practical use in a wide range of security environments due to its low cost, reliability, and ability to detect both beam interruption and direct object removal. The major applications include:

<u>1. Museum Artifact Protection</u>

The system is designed specifically to protect valuable artifacts by detecting:

- Removal of the object itself
- Hand movement or intrusion into the display area

This makes it ideal for exhibitions and museum showcases.

<u>2. Jewellery Store Display Security</u>

Jewellery shops often use glass cases with valuables placed inside.
Dual laser beams and an IR removal sensor can immediately detect:

- Theft attempts
- Opening of the glass case
- Removal of jewellery from its stand

3. Trophy and Award Showcases

Schools, universities, and institutions can use the system to protect trophies and awards displayed in open cabinets.

4. Home Showcase / Decorative Display Security

Homeowners can use the setup to protect decorative items, collectibles, and fragile objects.

5. Exhibition Booth Security

In trade shows or technical expos, models or gadgets on display can be protected using this system.

6. Sensitive Equipment & Research Labs

Laboratories can install such detectors around:

- Instruments
- Samples
- Tools or equipment that must not be touched

7. Anti-Tamper and Restricted Area Monitoring

Laser–LDR combinations can be scaled to detect unauthorized access across:

- Doors
- Windows
- Corridor entrances

ADVANTAGES

1. Dual-Level Protection

The combination of:

- Laser interruption detection, and
- IR artifact removal detection
  makes the system highly reliable.
  Even if one method is bypassed, the other triggers the alarm.

2. Fast and Accurate Response

Both LDR and IR sensors provide immediate feedback to the Arduino, enabling:

- Quick detection
- Fast buzzer activation
- Accurate OLED alerts

3. Low Cost and Easy to Build

The hardware consists of affordable components:

- Arduino Nano
- LDR sensors

- IR sensor
- 12V buzzer
- OLED display
- Sun board model

Ideal for student projects and low-budget security installations.

4. Visual and Audible Alerts

The system uses:

- Flashing Red LEDs
- High-power 12V buzzer
- OLED screen warnings
  ensuring alerts are hard to miss.

5. Modular and Expandable

More beams, IR sensors, or wireless modules (ESP32, GSM, RF) can be added easily.

6. Low Power Consumption

Lasers, LDRs, and sensors run on a stable 5V rail from the buck converter, drawing minimal power.

7. Stable Power System

The 12V-to-5V buck converter with custom PCB provides:

- Clean 5V output
- Protection against fluctuations
- No resets even when buzzer switches ON

8. Safe and Non-Invasive

The system uses:

- Low-power visible lasers (5 mW)
- Non-contact IR sensing
- No moving parts
  → zero risk to artifacts or users.

9. Real-Time Monitoring

OLED display continuously shows:

- Beam values
- Sensor status
- System state

This makes it very easy to debug or demonstrate the functionality.

LIMITATIONS

1. Laser Alignment Sensitivity

The system relies on accurate laser-to-LDR alignment.
Slight vibrations, physical movement, or misalignment over time can cause false alarms or reduced detection accuracy.

2. Ambient Light Interference

Strong sunlight, reflections, or room lighting can affect LDR readings.
Although thresholds minimize this issue, LDRs are inherently sensitive to ambient conditions.

3. IR Sensor Reflectivity Dependence

The IR sensor depends on the material and colour of the artifact.
Very dark, matte, or IR-absorbing materials may reduce reflectivity, requiring recalibration.

4. Limited Coverage Area

The current model uses only two laser beams.
An intruder could technically reach the object through an uncovered angle unless the physical layout is perfect.

5. Requires Manual Reset After Alarm

The system uses cooldown-based alarm locking.
It does not automatically reset or re-arm unless coded to do so, which limits convenience in real installations.

6. No Wireless Communication by Default

The current system does not send SMS, app notifications, or Wi-Fi alerts.
Detection is limited to local buzzer + LEDs + OLED.

FUTURE SCOPE

1. Add WiFi / GSM Alerts

Integrating ESP32, SIM800L, or IoT platforms can enable:

- SMS alerts
- Mobile app notifications
- Email alarms
- Cloud dashboard logging

This makes the system deployable.

2. Add More Laser Zones

Implementing 4–6 beams from multiple directions will provide:

- Full 360° coverage
- Zero blind spots
- A real “laser grid” experience

Mirrors or IR beams can also be added.

3. Add a Camera Module

Automatically capture images or short videos during intrusion:

- Identify intruder
- Provide evidence
- Real-time monitoring

4. Auto-Recalibration of Thresholds

Using algorithms to automatically adjust LDR and IR thresholds depending on ambient lighting to make the system self-correcting.

5. Replace LDR with Photodiodes / IR Break-Beams

Better speed, longer range, and less interference.
Invisible IR beams improve security and aesthetic clarity.

6. Implement Password-Based Arming / Disarming

Add a keypad or RFID module:

- Prevent false alarms
- Only authorized users can disable system

7. Battery Backup and Power Monitoring

Add:

- Built-in charger
- Battery percentage on OLED

This improves portability and reliability.

8. Integration With Home/Building Security Systems

The system can be expanded to interface with:

- Door locks
- Motion sensors
- Fire alarms
- CCTV systems

CONCLUSION

The developed **Laser and IR-Based Artifact Security System** successfully demonstrate a reliable and efficient method for protecting valuable objects using low-cost electronic components. By integrating **two laser–LDR intrusion channels** along with a **dedicated IR removal sensor**, the system ensures dual-layer protection, making it highly responsive to both beam interruption and direct object theft.

The **Arduino Nano** effectively handles real-time sensor monitoring, threshold evaluation, and alarm activation, while the **OLED display** provides live feedback and system status information. The **12V high-power buzzer** and **flashing red LEDs** deliver immediate audible and visual alerts during intrusion conditions. The system's power is regulated through a **buck converter and custom 5V PCB rail**, ensuring stable and noise-free operation even when the alarm is active.

The physical sun board model replicates a miniature museum environment, showcasing how real-world security systems protect artifacts in exhibitions, jewellery stores, and display cases. Overall, the project combines practicality, creativity, and engineering principles to create a compact and effective security prototype. It demonstrates strong understanding of sensors, embedded systems, and model integration, making it a valuable and successful engineering project.