Designs of lasers (LIDAR) and photodetection systems, quantum FPGA circuits for instrumentation of air navigation systems;

The atmosphere is a fluid that interacts with light due to its composition, which under normal conditions is made up of a wide variety of molecular species and small particles or aerosols. These physical and chemical properties change depending on time, altitude and geographic location (they are highly dependent on local and regional conditions). Most of these properties can be described at a suitable level by looking at the composition of what is generally called the standard atmosphere.

The linear transmission of a monochromatic light beam through the atmosphere:

$I(\lambda,t',x) = I(\lambda,t,0)e$

The elastic scattering of optical radiation due to the displacement of the electron cloud surrounding gaseous molecules that are disturbed by the incident electromagnetic field.

A laser **LIDAR** (Light Detection And Ranging) is an active remote sensing instrument, which means that it transmits electromagnetic radiation, captures and measures the radiation that is scattered back (backscattering), through a receiving device after it has interacted with various constituents of the atmosphere.

a system **LIDAR** uses a pulsed or continuous wave laser to propagate a beam through the atmosphere. The beam is expanded to minimize its divergence, and is directed towards the atmosphere by means of a tilted mirror. As it travels through the atmosphere, it is reflected or scattered by solid objects.

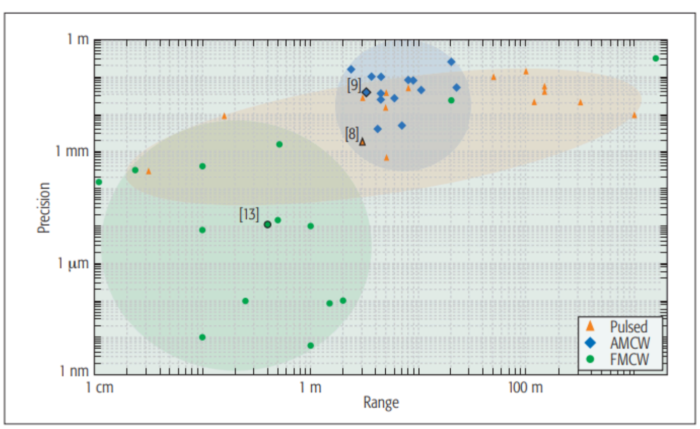


Figure 2. Precision vs. operating range for academically published and industrial lidars since 1990.

The most important performance metrics for a lidar-based 3D camera are its axial accuracy, lateral resolution, field of view (FOV), frame rate, transmission power in relation to eye safety, maximum operating range, light sensitivity, environmental and interference, energy consumption and cost.

Quantum circuit to implement FPGA structural components;

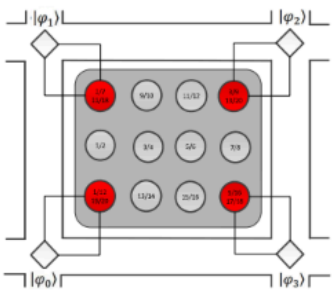


Fig. 7. The QLB-based realization of the diffusion operator D.

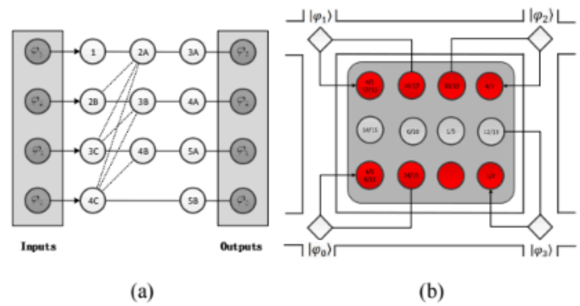
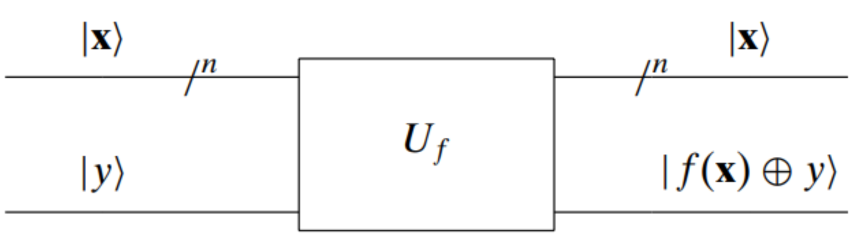


Fig. 9. (Color in electronic version) (a) The required cluster states of t

Algorithm for quantum circuit development;

$$\mathbf{H|0\rangle = \begin{bmatrix} \sqrt{\tfrac{1}{2}} & \sqrt{\tfrac{1}{2}} \\ \sqrt{\tfrac{1}{2}} & -\sqrt{\tfrac{1}{2}} \end{bmatrix} \begin{bmatrix} 1 \\ 0 \end{bmatrix} = \begin{bmatrix} \sqrt{\tfrac{1}{2}} \\ \sqrt{\tfrac{1}{2}} \end{bmatrix} = \frac{|0\rangle+|1\rangle}{\sqrt{2}}} .$$

A structure of the superposition of two possible input states. In this section, we solve the problem by introducing a superposition of all 2n possible input states. The function f will be given as a unitary matrix



In Lidar laser systems, FPGA designs can be implemented with quantum efficient algorithms, since these types of designs are viable for the components and materials, crystals
And ionization processes of materials and compounds, mirrors, filters and resonant cavities of a laser.

Variables of structural components in LIDAR laser;

Pt is the transmitted power, F(r) is the optical crossover factor of the transmitted beam with the field of view of the telescope in a range r, A is the area of the telescope (m^2), K is the optical efficiency of the system, is the reflectivity of the object (sr-^{1}), r is the target range (m), and T (r) is the total absorption coefficient (km-^{1}) of the atmosphere in the range r.

Laser beam characteristics

From the specification sheet of a commercial laser it is known:

- **Focusability:** (M^2) @ λ (n m) (method for measuring beam quality. It is based on the comparison of the beam to be measured with a pure Gaussian beam).
- **Beam divergence:**(i_{the}) @ λ (n m)

Implementation: Classic FPGA circuits with quantum component states and algorithms:

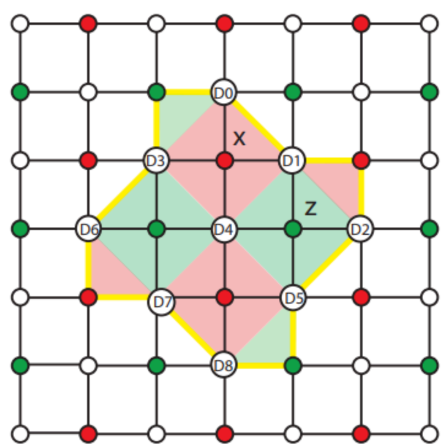
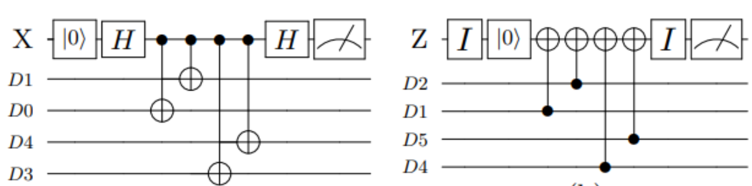


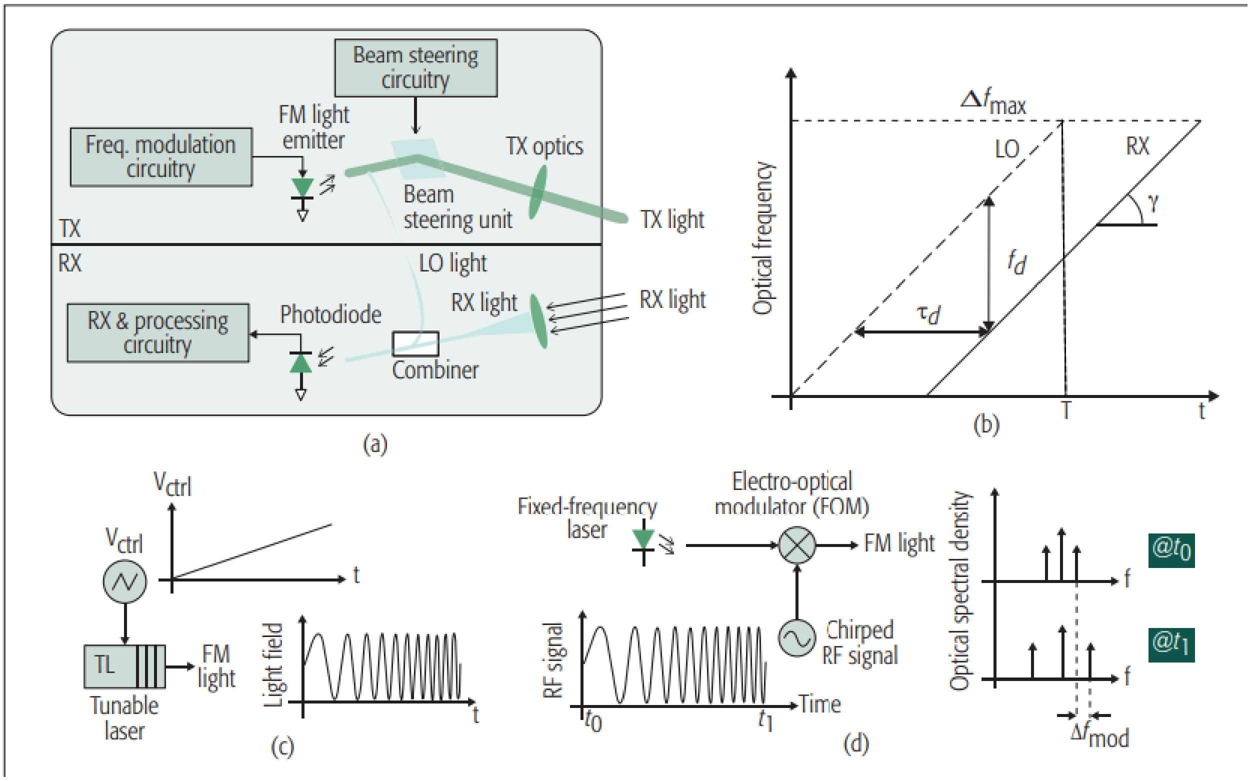
Figure 1: Implementation of the surface code 17, also called Ninja star.



(a) (b)

The circuits of aerial systems operate many of these instruments by radio frequency and RF and VHF systems, what is interesting about radio signal transmissions is exploring the possibility of incorporating software or hardware architectures associated with the transmission of signals or input and output that quantum cryptography and photodetection structures offer us but without the sole objective of detecting photons, but rather to understand how to detect magnetic waves and special signals within the context of the architecture of the circuits of an aircraft.

Architecture of reflective systems in LIDAR systems:



Aerosols equation: Using the LIDAR equation for aerosols and particles changes the reflectivity of the target:

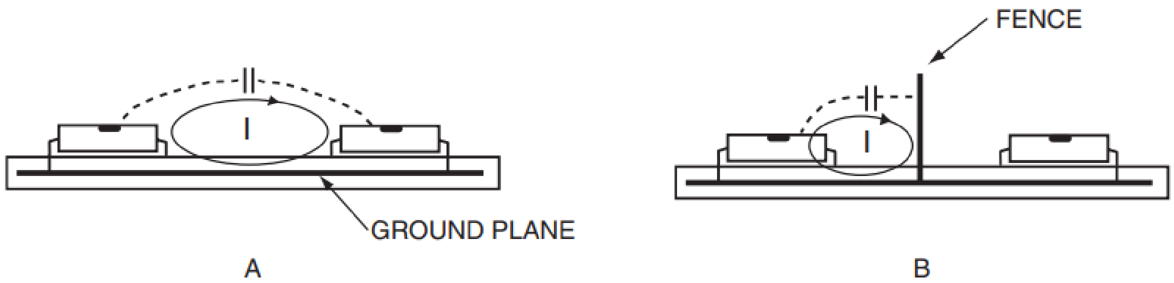
p = B(u,r)*c*r/2

The returned power is a function of the range Pr(*r*), and is determined by

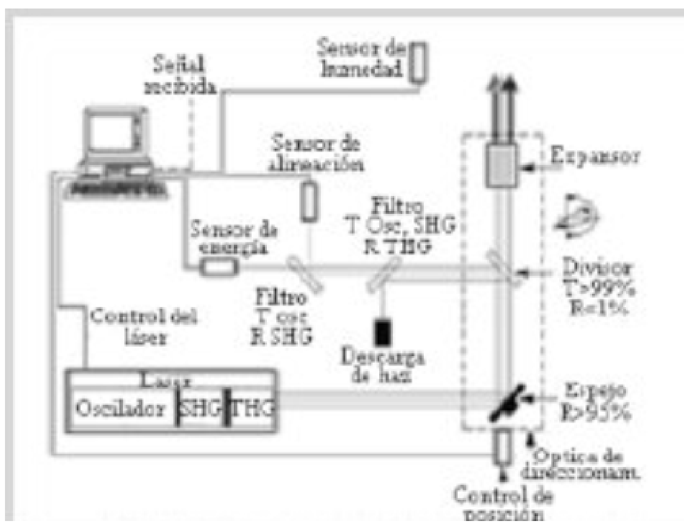
Optical components of the transmitting laser/receiving telescope in a LIDAR system determines the crossover factor F(R). This factor provides the fraction of the transmitted laser beam that progressively crosses the field of view of the telescope and is focused by it on the detector.

Aspect to take into account when defining the energy measurement method is that the shape of the pulse emitted by the laser remains approximately constant, so the peak value of the signal turns out to be a representative parameter with respect to the energy emitted per pulse.

Magnetic fields and resonance cavities:



The schematic of the transmission stage of a LIDAR system with a high energy laser that produces three wavelengths from a received signal, a humidity sensor, another sensor for power, energy sensor, oscillator, and T R Filter SHG, together with a mirror and 99% beam splitter



Sensors: The energy sensor measures the intensity of the beam emitted by the laser, so that its variations in the course of the experiments can be known, to enable the weighting of the measurements made of the return scatter signal with respect to the initial intensity.

The combination of options available for different lidar blocks can result in a wide variety of lidar architectures. Among them, the most popular schemes are pulsed amplitude modulated continuous wave (AM CW) and frequency modulated continuous wave (FMCW) and are discussed in this section. Pulsed lidar can provide moderate accuracy over a wide window of ranges. This is due to the fact that the nanosecond pulses used in these lenses typically have a high instantaneous peak power that can reach far distances while maintaining a low average power below the eye-safe limit. Furthermore, according to equation 2, the large bandwidth associated with short pulses can allow high-precision range measurements with acceptable relative range error even at short distances.

Quantum technology for CMOS could be implementations of quantum logic gates;

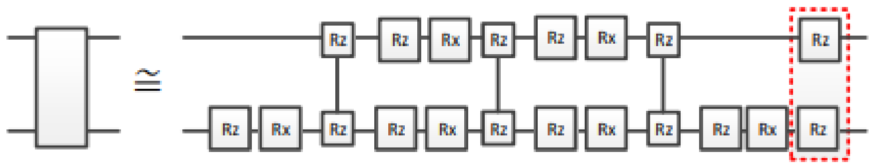
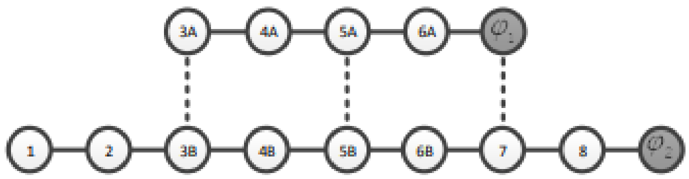


Fig. 3. The general decomposition of a two-qubit quantum gate.



CMOS technology; Charge transfer is controlled by two possible designs of electronic transfer gates in a CMOS circuit, TG1 and TG2. For short distances to the target, most of the charge generated by the return light is transferred to the Q1 node. For longer distances, the return light experiences more delay and therefore less charge is transferred to node Q1 and more appears at node Q2. Therefore, the ratio of charge collected at these two nodes is a measure of flight time. Time-of-flight to charge conversion makes this architecture fully compatible with conventional RGB CMOS pixels that translate ambient light intensity into accumulated charge.

Matrix notations for quantum architectures in Intercom and audio control in light aviation:

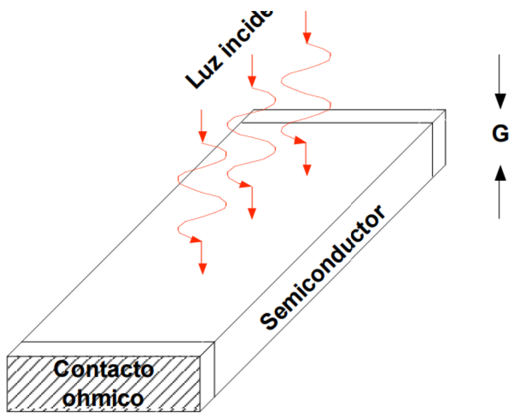
X = ⌈ | ⌊ 0 1 1 0 ⌉ | ⌋ , Y = ⌈ | ⌊ 0 −i i 0 ⌉ | ⌋ , Z = ⌈ | ⌊ 1 0 0 −1 ⌉ | ⌋ .

Laser photodetection:

Under the influence of an electric field established in the material due to the application of a potential difference in it, electrons and holes can be swept through the semiconductor, resulting in an electric current called photocurrent [1], If, which is directly proportional to the incident optical power Pin: Ip = RPin,

(Obstacle Detection)Axial precision and 3D images for obstacle detection in vehicles that incorporate LIDAR lasers:

An optical receiver converts the optical signal coming from the optical fiber into the electrical signal and recovers the transmitted data. Its input element is the photodetector, which converts light into electric current through the photoelectric effect. Optical receivers, in general, must have high sensitivity, fast response, low noise levels, low cost and high reliability. In the case of fiber optic systems:

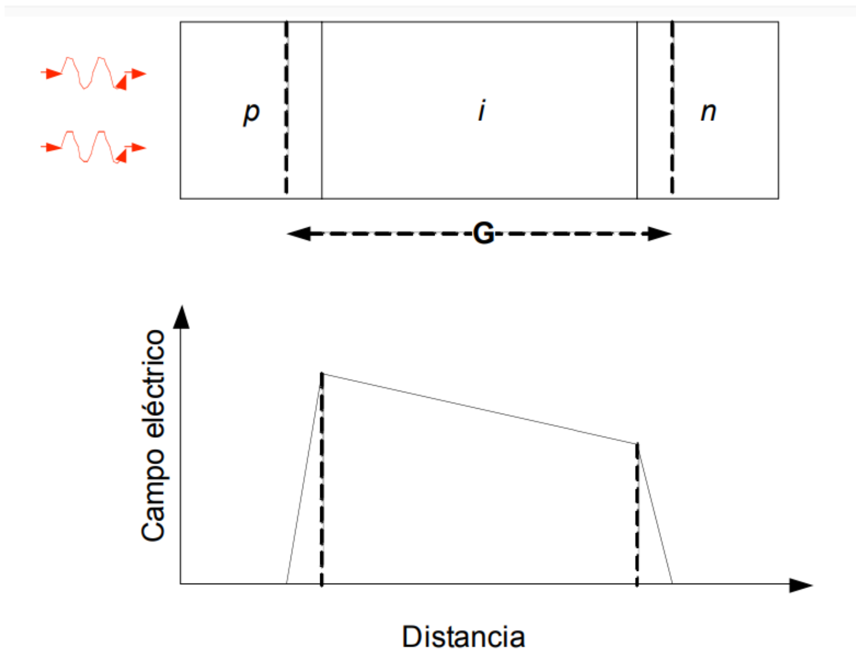


Axial precision in LIDAR images: The terms axial or range precision refer to the standard deviation of multiple range measurements made for a target at a fixed distance (sR). This should not be confused with range resolution (dR). Range resolution refers to the lidar's ability to resolve multiple closely spaced targets in
the axial direction. For example, when 3D images are taken of an organic tissue, the emitted light is reflected at the interfaces between different layers of the tissue.

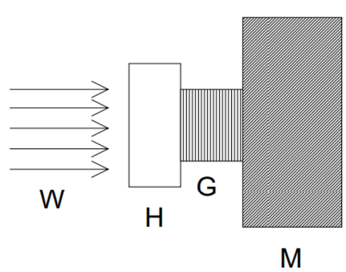
Photon absorption coefficient: The dependence of η on λ can be expressed through the absorption coefficient α. If the faces of the semiconductor in Figure 4.1 had an anti-reflective coating, the power transmitted through the tablet of thickness G would be: ! Pir = exp("#G)Pin

Depending on the physical parameter that varies as a result of the heating of the sensitive element, there are several types of thermal detectors: - Thermocouple: the sensitive element is in contact with the hot end of a thermocouple. - Bolometer: the sensitive element is a conductive layer whose resistance varies with temperature. - Golay or pneumatic detector: the sensitive element heats a gas in an enclosure and the gas pressure variations cause the displacement of a membrane. This displacement will be proportional to the luminous flux. - Pyroelectric: the sensitive element is a ferroelectric crystal whose heating changes its spontaneous polarization, causing a small current through a resistance.

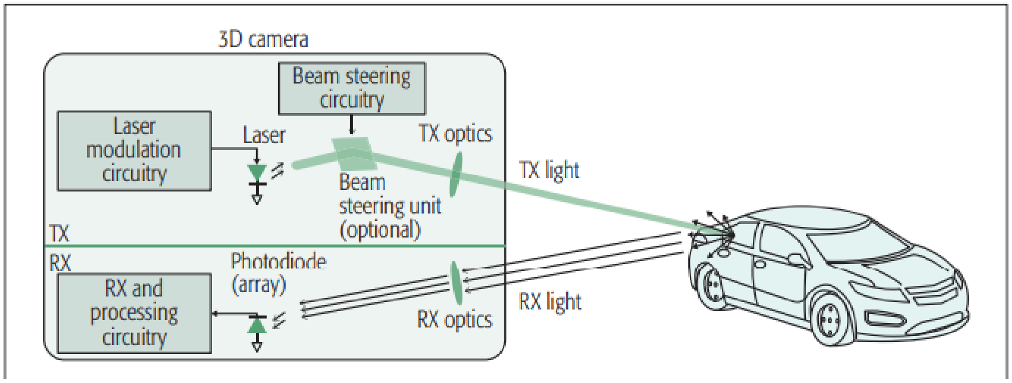
The bandwidth d of a p–n photodiode is generally limited by the transit time τtr in equation (4.1.10). If G is the width of the depletion region and vd is the travel speed, the transit time is given by: ! "tr = G vd



The figure shows the schematic of a thermal detector. It consists of a sensitive element S with thermal capacity H, in contact (through a thermal bond of thermal conductance G) with a thermal mass M that is maintained at a constant temperature. If the sensitive element receives an energy flow W, the energy absorbed in a time interval dt will be Wdt, which will give rise to an increase in temperature ΔT. The heat transmitted to the thermal mass will be GΔTdt.



Axial precision with laser circuit modulation and the beam splitter:

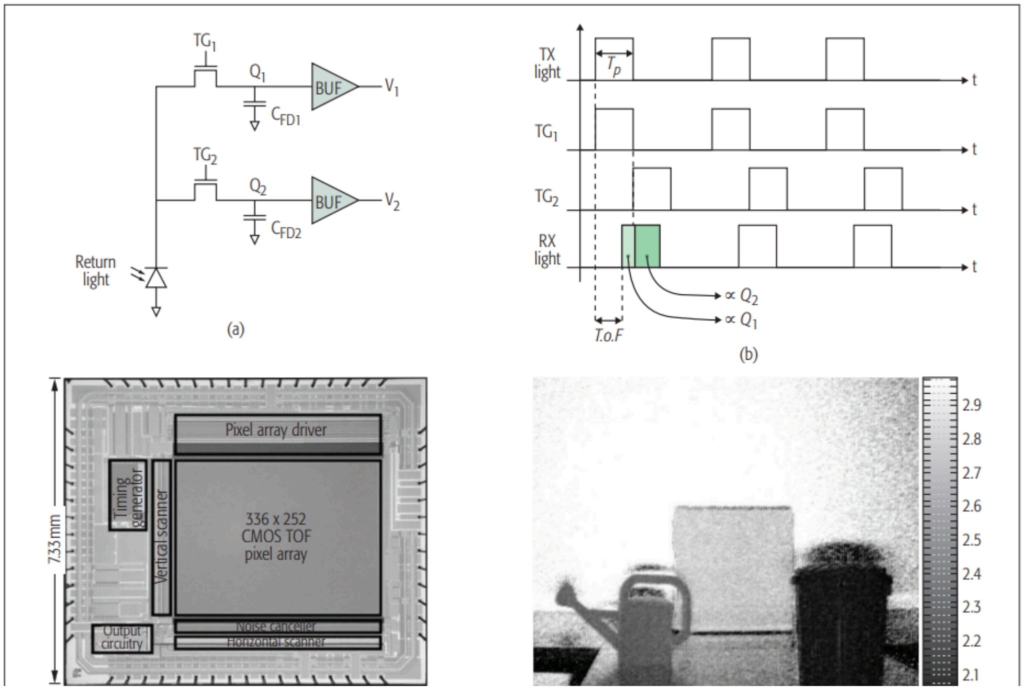


In the particle-photon reception stage, there are two basic configurations. The bistatic arrangement involves considerable separation of the transmitter and receiver to achieve spatial resolution. Currently, this arrangement is rarely used, so in most cases a configuration is mono-static. A monostatic lidar can be *coaxial or biaxial.* In a coaxial system the axis of the laser beam is coincident with the axis of the receiving optics, while in the biaxial arrangement the laser beam *enters* or if *overlaps* to the field of view of the optical receiver from some predetermined range.

In the technical structures of the device such as the electric field distribution within it when under reverse polarization. The intermediate layer, because it is intrinsic, has a greater resistance, and most of the voltage drop occurs through it, therefore there is an intense electric field in said layer i, noise interference or resonances may appear here;

Circuit and photodetection diagrams for circuits in LIDAR systems.
AMCW lidar used in a CMOS imager for 3D depth measurement in

a) pixel topology;
b) timing diagram;
c) chip photomicrography; d) 3D image of the scene

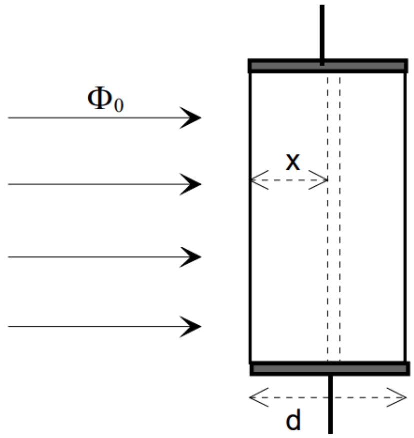


Frequency tuning occurs purely in the optical domain, while with an electro-optical modulator, frequency tuning occurs in the electrical domain and is used to modulate the frequency of the light in another step. The modulation bandwidth of a tunable laser can reach beyond 10 THz, which cannot be achieved by electro-optical modulation. Therefore, architectures based on tunable lasers are more suitable for applications where deep submillimeter resolution is needed.

Optical materials are necessary in aerospace applications due to the complexity of electro-optical systems that operate in multiple wavelength regimes and travel at high speeds and in harsh environments. Emphasis on optical performance for accurate information transfer is critical due to the life or death nature of the circumstances. Since the accuracy of this information is directly affected by the interaction of the photons with the exterior optics themselves, the optical wavefront, transmission, and refractive index temperature coefficient are critical performance metrics.

Carrier concentration (magnetic fields)

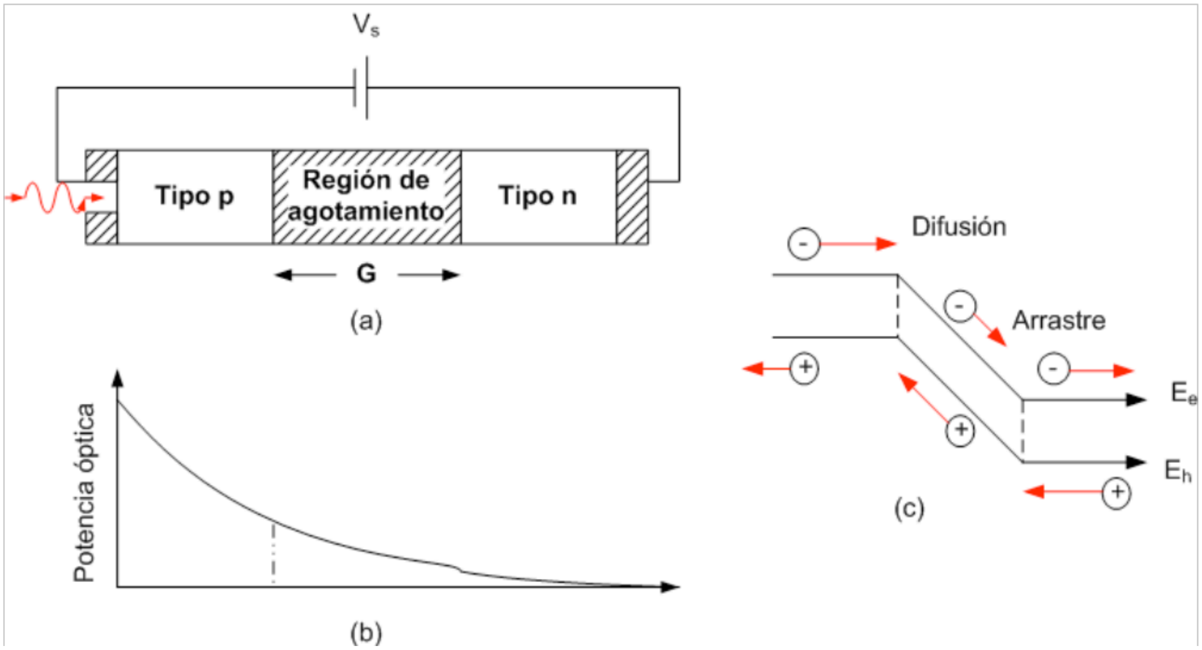
The concentration of carriers will not be constant, to calculate the change in conductance of the sample, we must calculate the change in conductance of the element of thickness dx, and integrate for the entire thickness of a sample where integral variables are established for the thickness of the material : ∫ Δ = + Δ d e e n x dx l a e e 0 σ (μ μ) ( ) where l is the length of the sample and a its width. To calculate Δn we will solve the diffusion equation, assuming that on the surfaces of the sample the surface recombination rate is zero (which sets the boundary conditions for the diffusion equation).



Photodiodes: , the simplest type of detector corresponds to the p-n junction of a semiconductor whose energy interval between the valence and conduction bands is small, which will allow a photon incident on the junction to have enough energy to allow the creation of an electron – hole pair. The detection of a beam of wavelength λ requires the use of a material in the detector whose energy gap is smaller than the energy hc/λ. For wavelengths in the first window, the most suitable material is silicon, with an energy gap of 1.1eV. In the second window (longer wavelengths) elements with a greater energy jump will be required, such as germanium (0.7 eV), which has the disadvantage of a high dark current and high sensitivity to temperature for its use in the third window. Compounds from periods III and V, such as In, Ga, As and P, constitute optimal semiconductors.

A reversely polarized p–n junction consists of a region known as the depletion region or depletion region, which is devoid of free charge carriers and within which a strong electric field is established that opposes the flow of electrons from the n side. to the p side (and to the flow of holes from the p side to the n side).

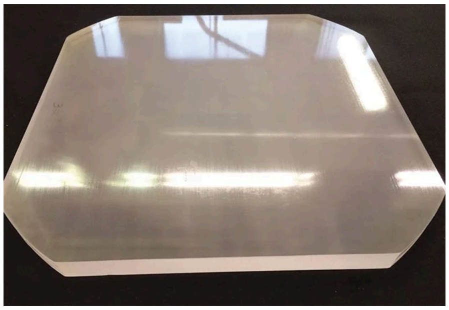
The performance of p-i-n photodiodes can be improved if dual heterostructure designs are used. Similar to the case of semiconductor lasers, region i is surrounded by p- and n-type cladding layers of a different semiconductor material whose bandgap is chosen such that light is absorbed only in the intermediate layer i. A photodiode commonly used in optical communications uses InGaAs for the middle layer and InP for the surrounding p and n layers.



Photonics materials for LIDAR lasers:

The near-to-mid-infrared region (1 to 5 µm) has always been important to defense and aerospace due to the ubiquitous nature of infrared sensors, detectors, and cameras. Visible regions are also important for cameras and other systems that operate in this range. Materials such as sapphire, spinel and ALON satisfy both infrared and visible requirements, and all operate in the ultraviolet region to varying degrees. Sapphire is a single-crystalline material with a hexagonal structure, a melting point of 2040 °C, a hardness of 9 out of 10 on the Mohs scale (diamond measures 10) and a refractive index of 1.76. Sapphire is grown from a seed crystal in a high temperature furnace using a variety of methods including the heat exchange method (HEM) and a low absorption optical sapphire (LAOS) process.

The HEM makes it possible to obtain large diameter sapphires of up to 23 inches and heights of up to 13 inches, with a mass of up to 300 kg. Crystals are grown in an ascending manner, with the seed crystal located at the bottom of a crucible. This process uses a seed in the A plane, resulting in the crystal growing in the direction of the A plane. High purity starting material is placed on the seed and then taken to the oven at a temperature above 2040° c. The crucible and seed glass sit above a heat exchanger, which provides a cool place so the seed doesn't melt completely. The peripheral edges of the seed are allowed to melt slightly, after which the temperature in the seed is reduced and the growth process begins.



The LAOS manufacturing process also produces large, high-purity sapphire balls with diameters up to 13 inches. However, LAOS crystals have shown mass absorption values less than 20 ppm at 1064 nm, which is lower than sapphire created by other methods. Their spectral transmission ranges from 0.15 to 5 µm, and these large crystals may not have birefringence. Additionally, LAOS crystals have been optically fabricated for transmitted wavefront values of 1/40 of a P-V wave at 632 nm, meeting the stringent optical requirements for applications such as HELs.

Key comparison metrics for common materials used for window and laser applications

	HEM Sapphire	Spinel	ALON
Chemical Formula	Al_2O_3	$MgAl_2O_4$	$(AlN)_x \cdot (Al_2O_3)_{1-x}$, $0.30 \leq x \leq 0.37$
Crystal/Ceramic	Single crystal	Polycrystalline ceramic	Polycrystalline ceramic
Crystal Structure	Hexagonal system (rhombohedral)	Cubic system	Cubic, spinel system
Melting Temperature	Approx. 2040 °C	Approx. 2135 °C	Approx. 2150 °C
Transmission Range	0.15 to 5 µm	0.25 to 6.5 µm	0.20 to 5 µm
Mohs Hardness	9	8	8
Knoop Hardness	1525 to 2000 kg/mm² (0.2 kg load)	1650 kg/mm² (0.2 kg load)	1800 kg/mm² (0.2 kg load)
Refractive Index	1.76	1.72	1.79
Thermal Conductivity	40 W/mK	25 W/mK	13 W/mK
Density	3.98 g/cm³	3.58 g/cm³	3.70 g/cm³
Coefficient of Thermal Expansion	8.4×10^{-6}/°C	7×10^{-6}/°C	6×10^{-6}/°C
Dieletric Constant	9.4 to 11.5 at 1 MHz	8.2 at 1 MHz	8.5 at 1 MHz
Homogeneity of Refractive Index	<1 ppm	5 ppm	10 ppm
Absorption @ 1064 nm	<1 ppm/cm	700 to 1000 ppm/cm	700 to 1000 ppm/cm

ALON

ALON, or aluminum oxynitride, is a polycrystalline ceramic that may be familiar from some references to this type of material as "transparent aluminum." ALON is actually a ceramic that contains the elemental composition of aluminum, oxygen and nitrogen. The material is produced in a process that heats and shapes very fine, graded particles that cool and condense into a cubic spinel structure. This process allows the creation of nearly net-shaped parts whose geometry closely matches that of the final shape of the desired finished part. ALON is an optically isotropic ceramic with a spectral transmission range of 0.20 to 5 µm in its polycrystalline form, measures 8 on the Mohs scale, and has a refractive index of 1.79.

Aerospace applications require very robust materials that can withstand harsh environments, extreme temperature changes, and direct contact with atmospheric conditions such as debris and water. Aircraft and missiles routinely exceed Mach 1 during flight, and UAVs are also capable of high flight speeds. The window materials on board these vehicles must be able to withstand the heat and thermal load caused by rapid acceleration. The force of high-speed impact from rain, sand and birds is another environmental factor that these materials must withstand. Sapphire, spinel and ALON have demonstrated the ability to succeed in these conditions.

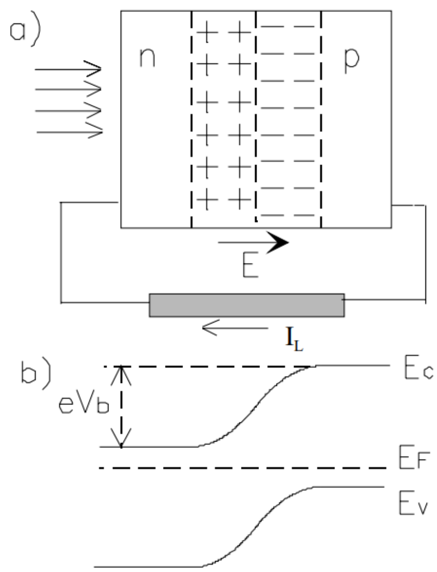
C-plane sapphire is a widely used material in air-to-air missiles due to its high transmittance in the useful range of 3 to 5 µm and its hardness and resistance to thermal shock. ALON and spinel are also used for missile radomes and are not birefringent. However, the thermal shock resistance of these materials is about half that of sapphire (175 vs. 80 Btu/(ft2-s))1. Among the materials tested, which included sapphire, spinel, ALON, yttria, zinc sulfide and germanium glass, sapphire proved to be the most capable of withstanding thermal shock. Typical dome diameters range from 3 to 6 inches, but C-plane sapphire can be made up to 13 inches.

Materials such as sapphire, spinel and ALON satisfy VIS and IR requirements, and all operate in the UV region to varying degrees. Subsea applications have their own specific requirements. In this case, optical materials must withstand high pressures that increase to 1 bar (14.7 psi) per 10 m. Therefore, underwater optics operating at 300 m (1,000 ft) depth will experience pressures of 30 bar (441 psi) with continuous immersion in salt water, all while maintaining optical precision and mechanical strength. Sapphire has been used as part of the optical assembly of certain classes of nuclear submarines for many years. Newer sapphire optical manufacturing processes and techniques have placed more emphasis on this material for submersible applications.

High-power lasers have received considerable attention and government funding due to their practicality, flexibility, ability to deal with multiple threats, and cost-per-shot economy. High-power laser systems require an output window that is non-birefringent and highly homogeneous, and has very low intrinsic losses. The window will be polished to angstrom levels with an optical shape that supports transmitted wavefronts of 1/10 of a P-V wave or better. The importance of a low absorption material cannot be overstated, as small power absorption in the kilowatt or hundreds of kilowatt regimes would cause heat gradients in the window that could be catastrophic for the laser system itself.

Laser photodetection:

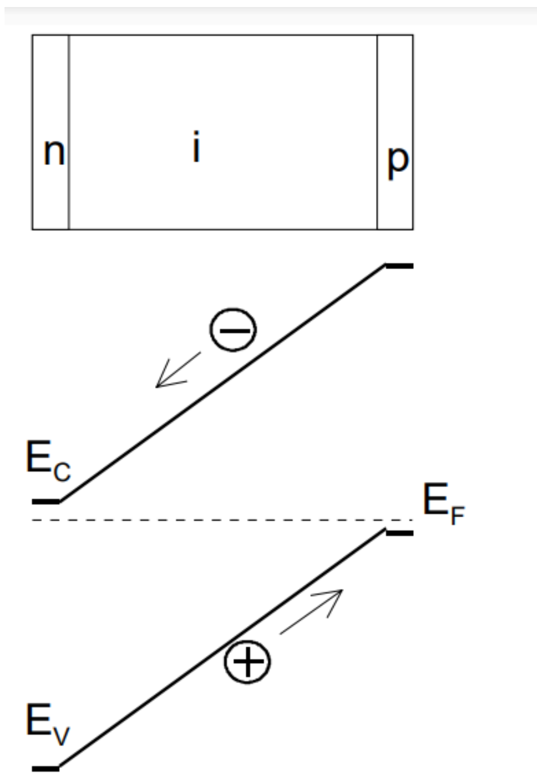
If the sample material is thick, the absorption coefficient large or, the absorption being low in resonant cavities, there is strong surface recombination, the change in sample conductance must be obtained from the diffusion equation. Let's consider a sample with the geometry of figure 1. If we call R the reflectivity of the sample, the luminous flux at a depth x will be given by relationships between different variables (x x R e)



SPECTRAL RESPONSE OF A PHOTODIODE As we have pointed out, the photocurrent in a photodiode has two contributions, that of the depletion zone, of width W, and that of the P zone (the contribution of the n zone can be neglected because it is very thin) In the depletion zone, all carriers are generated in the field zone and all contribute to the current. If Φo is the incident flux, the flux of excited carriers will be equal to the flux of photons absorbed by the zone of thickness W, and the associated current density will be J = e (1- R)(1- e)

TEMPORARY RESPONSE IN A PHOTODIODE In the temporal response of the photodiode, we must consider, first of all, the intrinsic response, which has to do with the parameters of the material and the device, and corresponds to the time it takes for the photocurrent to establish itself upon instantaneous illumination. the diode. On the other hand, we must consider the circuit response, linked to the fact that the diode has a certain capacity and is in an electrical circuit that includes a load resistance. In the intrinsic response, in turn, two times must be taken into account: a) Average life time of the minority carriers, which determines the establishment and disappearance of the concentration of minority carriers in zone P. b) Transit time , which is the time it takes for the carriers to traverse the space loading zone. In a linear approximation, and with the diode in reverse bias conditions, we can obtain an approximate value of the mean field by dividing the applied voltage ε 0 RL 8 by the width of the depletion zone E=V/W. The speed of the carriers will be: v =μE

When a fast response is sought, the most convenient solution is to eliminate the neutral zone, which is achieved through a p-i-n structure, in which, between two very thin p and n zones, there is a much thicker intrinsic semiconductor zone. . In said intrinsic zone there will be a uniform field, since there is no space charge. If the thickness of the intrinsic zone is d, in thermal equilibrium, the field will be approximately E=Eg/ed. In reverse polarization, the field will be E=V/d.



The transit time will be V d E d v d t μ μ τ 2 = = = , while the circuit time will be determined by the dielectric capacity of the semiconductor d A C = ε ,