Contents

Abbreviations

Abbreviations	*Phrase*
2D	Two Dimensional
3D	Three Dimensional
AC	Anterior Chamber
ACA	Anterior Chamber Angle
ACD	Anterior Chamber Depth
ACG	Angle Closure Glaucoma
ACV	Anterior Chamber Volume
ALPI	Argon Laser Peripheral Iridoplasty
ALT	Argon Laser Trabeculoplasty
Anti-VEGF	anti-Vascular Endothelial Growth Factor
APAC	Acute Primary Angle Closure
AS-OCT	Anterior Segment Optical Coherence Tomography
AUC	Area Under the receiver operating characteristic Curve
BF	Blood Flow
BL	Borderline
BOT	Blowout Time
C/D ratio	Cup/Disc ratio
CB	Ciliary Body
CC	Corneal Compensation
CCD	Charge-Coupled Device
CLASS	Carbon dioxide Laser-Assisted Deep Sclerectomy Surgery
CMOS	Complementary Metal–Oxide–Semiconductor
CO_2	Carbon dioxide
CP	Ciliary Processes
CPA	Corneal Polarization Axis
CPC	Cyclophotocoagulation
CPM	Corneal Polarization Magnitude
CSLO	Confocal Scanning Laser Ophthalmoscopy
CW	Continuous Wave

DM	Descemet's membrane
DS	Deep Sclerotomy
ECC	Enhanced Corneal Compensator
ECM	Extracellular Matrix
ECP	Endoscopic Cyclophotocoagulation
ELT	Excimer Laser Trabeculostomy
Er:YAG	Erbium Yttrium Aluminium Garnet
Etc	et cetera
FCC	Fixed Corneal Compensator
FDF	Flicker-Defined-Form
FD-OCT	Fourier Domain Optical Coherence Tomography
fs	Femtosecond
GCL	Ganglion Cell Layer
GLT	Glaucoma Laser Trial
GON	Glaucomatous Optic Neuropathy
GPA	Guided Progression Analysis
GPS	Glaucoma Probability Score
HD	High Definition
HEP	Heidelberg Edge Perimeter
HM	Hand Motion
HRF	Heidelberg Retina Flowmeter
HRT	Heidelberg Retinal Tomography
IOP	Intraocular Pressure
IPL	Inner Plexiform Layer
IQ	Iridex Corporation
Laser	Light Amplification by Stimulated Emission of Radiation
LGP	Laser Goniopuncture
LPI	Laser Peripheral Iridotomy
LSFG	Laser Speckle Flowgraphy
LT	Laser Trabeculoplasty
MBR	Mean Blur Rate
MD	Mean Deviation
MDLT	Micropulse Diode Laser Trabeculoplasty
MIGS	Microinvasive Glaucoma Surgery

mJ	Mégajoule
mm^2	Square Millimeter
MMC	Mitomycin C
mmHg	Millimeter Mercury
MRA	Moorfields Regression Analysis
ms	Microsecond
mW	milliWatt
Nd: YAG	Neodymium-doped Yttrium Aluminium Garnet
Nd: YLF	Neodymium-doped Yttrium Lithium Fluoride
NFA	Nerve Fiber Analyzer
NFI	Nerve Fiber Indicator
Nm	Nanometer
NPDS	Non-Penetrating Deep Sclerectomy
ns	Nanosecond
NVG	Neovascular Glaucoma
OAG	Open Angle Glaucoma
OCT	Optical Coherence Tomography
OHTS	Ocular Hypertension Treatment Study
ON	Optic Nerve
ONH	Optic Nerve Head
ONL	Outside Normal Limits
PAC	Primary Angle Closure
PACG	Primary Angle Closure Glaucoma
PAS	Peripheral Anterior Synechia
PC	Posterior Chamber
POAG	Primary Open Angle Glaucoma
RNFL	Retinal Nerve Fiber Layer
RPE	Retinal Pigment Epithelium
RVM	Relevance Vector Machine
SAP	Standard threshold Automated Perimetry
SBR	Square Blur Rate
SC	Schlemm's Canal
SD	Standard Deviation
SD-OCT	Spectral Domain Optical Coherence Tomography

SL	Schwalbe's Line
SL-OCT	Slit Lamp plus Optical Coherence Tomography
SLP	Scanning Laser Polarimetry
SLT	Selective Laser Trabeculoplasty
SS	Scleral Spur
TCA	Topographic Change Analysis
TCP	Transcleral Cyclophotocoagulation
TDM	Trabeculo-Descemet's Membrane
TD-OCT	Time Domain Optical Coherence Tomography
TEM	Transverse Electromagnetic Mode
TICV	Trabecular Iris Circumference Volume
TISA	Trabecular Iris Space Area
TM	Trabecular Meshwork
TSLT	Titanium Sapphire Laser Trabeculoplasty
TSNIT	Temporal, Superior, Nasal, Inferior and Temporal
TSS	Typical Scan Score
UBM	Ultrasound Biomicroscopy
UHR-OCT	Ultrahigh Resolution Optical Coherence Tomography
µL	Microliter
µm	Micrometer (micron)
µs	Microsecond
VA	Visual acuity
VCC	Variable Corneal Compensator
VF	Visual Field
vs.	Versus
w	Waist (size)
W	Watt
WNL	Within Normal Limits

List of Figures

List of tables

Introduction

Today, the term glaucoma does not refer to a single disease entity, but rather to a group of diseases that differ in their clinical presentation, pathophysiology, and treatment. These diseases are grouped together because they share certain features, including cupping and atrophy of the optic nerve head (ONH), which has attendant visual field (VF) loss and is frequently related to the level of intraocular pressure (IOP) **(Stamper et al, 2009)**.

The anterior chamber angle (ACA) is the actual angle created by the root of the iris and the peripheral corneal vault. Within it lie the important structures involved in the outflow passages of aqueous, specially the trabecular meshwork (TM) and Schlemm's canal (SC). The aqueous leaves the anterior chamber (AC) through the TM. If the aqueous humor cannot properly drain out of the eye, the pressure can build up inside the eye, causing glaucoma **(Carolyn Shea et al, 2008)**.

Laser imaging devices have been suggested as possible diagnostic methods in order to overcome the variability caused by subjective responses and has been used worldwide for glaucoma diagnosis **(Stamper et al, 20009)**.

The use of lasers in glaucoma treatment continues to evolve, with a trend towards primary and earlier intervention, as well as refractory glaucomas. Newer laser modalities show promise as alternatives and adjuncts to topical medications and non-penetrating surgery. Additional research is needed to better define their safety and efficacy **(Meyer and Lawrence, 2012)**.

Aim of the work

The aim of this essay is to discuss the latest uses of laser in diagnosis & treatment of glaucoma.

Laser in glaucoma

Introduction of laser:

The word laser was originally the upper-case LASER, the acronym from Light Amplification by Stimulated Emission of Radiation, wherein light broadly denotes electromagnetic radiation of any frequency, not only the visible spectrum; hence infrared laser, ultraviolet laser, etc. Because the microwave predecessor of the laser, maser, was developed first, devices that emit microwave and radio frequencies are denoted “masers”. In the early technical literature, especially in that of the Bell Telephone Laboratories researchers, the laser was also called optical maser, a currently uncommon term; moreover, since 1998 Bell Laboratories adopted the laser usage. The word laser sometimes is used in an extended sense to describe a non-laser technology, for example a coherent-state atom source is an atom laser **(Nitish et al, 2011)**.

History of laser development:

Theodore Maiman was the first to demonstrate the earliest practical laser in 1960 after the reports by several scientists. Maiman’s first laser was based on optical pumping of synthetic ruby crystal using a flash lamp that generated pulsed red laser radiation at 694 nanometers (nm) (**Maiman, 1966)**.

Iranian scientists Javan and Bennett made the first gas laser using a mixture of Helium and Neon gases in the ratio of 1:10 in the 1960 **(Javan et al, 1961)**.

Hall demonstrated the first diode laser made of gallium arsenide in 1962, which emitted radiation at 850 nm, and later in the same year the first semiconductor visible-light-emitting laser was developed **(Singh et al, 2012)**.

The device produces a beam of coherent light with a specific wavelength in the infrared, visible or ultraviolet regions of the electromagnetic spectrum. Further development of this technology led to lasers becoming widely used in medical practice **(Simpson, 2012)**.

Idea of stimulated emission of light:

In contrast to sunlight for example, which is emitted spontaneously, laser light is emitted by stimulated emission. The concept of stimulated light emission, which the generation of laser light is essentially based on, was originally conceived by Albert Einstein in 1917, clearly long before the first laser was invented **(Einstein, 1917)**.

For stimulated emission of radiation to happen, an already excited electron has to collide with yet another photon with the proper energy, which will lead to the emission of two photons when the electron returns to resting state. Importantly, these two photons will contain the same energy, frequency, and direction. Finally, such emitted photons can again stimulate the emission of further photons. Stimulated emission needs a source of energy to induce the change. In the case of lasers, we have several sources of stimulation, referred to as the ‘pump’ portion of the device. This increasing stimulation of photon emission will ultimately lead to an environment where there are proportionately higher numbers of atoms in the excited state as compared to the resting state. This situation is called ‘population inversion’ and is a crucial prerequisite for the generation of laser light within an optical chamber. **(Bogdan Allemann and Goldberg, 2011)**.

Properties of laser beams:

Laser radiation is characterized by an extremely high degree of monochromaticity, coherence, directionality and brightness. A fifth property can be added, short time duration. This refers to the capability for producing very short light pulses, a property that, although perhaps less fundamental, is nevertheless very important **(Orazio Svelto and David Hanna, 2010)**.

Monochromaticity: *The frequency emitted by the laser is given by the difference in energy between the energy levels for which there is radiation emission. It is given by Planck`s relationship:*

$$v_0 = \frac{E_2 - E_1}{h}$$

where: h is the Planck`s constant; E2 – upper level energy; E1 – lower level energy.

The two energy levels between which is laser radiation emission occurs are stable. Thus a single frequency is emitted and amplified in the optical cavity. This means that laser radiation has a single wavelength. This means that the radiation emitted by the laser is monochromatic.

Coherence: *Coeherence of electromagnetic radiation means maintaining a constant phase difference between two points of wave front the wave. Coeherence is of two types: spatial and temporal. Spatial coherence is limited to a given area and the temporal coherence is limited to a certain time. Laser radiation have high spatial and temporal coherence compared with conventional light sources.*

Divergence and directionality: *The propagation and directionality of radiation is described by diffraction theory. Maximum intensity of radiation is limited by the angle of divergence. In the laser medium will be amplified only radiation propagated on direction of optical cavity axis. Construction of optical cavity leading to a low beam divergence which means a high directionality. For perfectly coherent radiation of aperture D space there will be a given divergence angle ftom diffraction theory. Angle of divergence is given by (B=1.1 is a factor of probability):*

$$\Theta_d = \beta . \frac{\lambda}{D}$$

Brightness: *The brightness of a light source is defined as the power emitted per unit area and unit solid angle. Maximum brightness is obtained if the radiation emitted is spatially coherent* **(Ramona Laslau et al, 2010)**.

Short time duration: *by means of a special technique called mode locking, it is possible to produce light pulses whose duration is roughly equal to the inverse of the linewidth of the 2 to 1 transition. Thus, with gas lasers, whose linewidth is relatively narrow, the pulse-width may be of about 0.1–1 ns. Such pulse durations are not regarded as particularly short and indeed even some flashlamps can emit light pulses with a duration of somewhat less than 1 nanosecond (ns). On the other hand, the linewidth of some solid state and liquid lasers can be 103–105 times larger than that of a gas laser, and, in this case, much shorter pulses may be generated, down to about 10 femtoseconds (fs). This opens up exciting new possibilities for laser research and applications* **(Orazio Svelto and David Hanna, 2010)**.

Electromagnetic modes are standing waves that were formed in the optical cavity. The laser cavity stimulated radiation propagates between the mirrors. Waves for which the propagation distance (twice the cavity length) are whole numbers of wavelengths are standing wave in the cavity. These are called longitudinal electromagnetic modes. Their number is relatively low (below 10) between them is a difference in frequency. Importance in practice is a laser intensity distribution in laser beam section. This means transverse electomagnetice modes TEMplq. Indices have the following meaning: p – radial number of fields; l – the number of angular fields; q – the number of longitudinal modes. Index q is excluded, it is considered a single longitudinal mode, so the discussion comes down to the first two indices. Electromagnetic mode TEM00 is named fundamental mode. It has the most concentrated intensity and provides the best focusing properties. He is also called the Gaussian beam because intensity distribution follows Gauss curve, a great maximum followed by a stronger than exponential decrease of intensity. He also is known as single mode beam. Laser beam quality parameter is given by beam propriety product. It is the product of size w (waist) of unfocus beam and divergence angle θ **(Ramona Laslau et al, 2010)**.

Laser in glaucoma diagnosis and treatment:

When laser light interacts with ocular tissue, it is either reflected, scattered, transmitted or absorbed. Clinically useful laser–tissue interactions can be classified as photochemical, thermal (photocoagulation and photothermoablation) or ionizing (Figure 1). Light in the range of 400–1100 nm will easily pass through cornea, aqueous, lens, and vitreous. In current glaucoma therapy, intraocular laser effects are achieved by two main mechanisms. In the first mechanism, spatial confinement of photons occurs by absorption of photons by the ocular chromophores: melanin, hemoglobin, and xanthophyll or water. The deposition of energy at first causes denaturation of proteins as the tissue temperature rises. This is clinically useful for iridoplasty or coagulation of bleeding vessels. If irradiance is greatly increased (continuous wave power/area) thermally induced focal destruction of the target tissue occurs (photocoagulation). If the temperature rises above the boiling point of water, a steam bubble is seen to form, which contains water vapor and gaseous by products of the tissue destroyed. This produces a typical laser ablation in which both the surrounding edema zone of thermally altered tissues decreases and energy needed decreases (Figure 2) as spatial confinement of energy increases **(Choplin and Lundy, 2007)**.