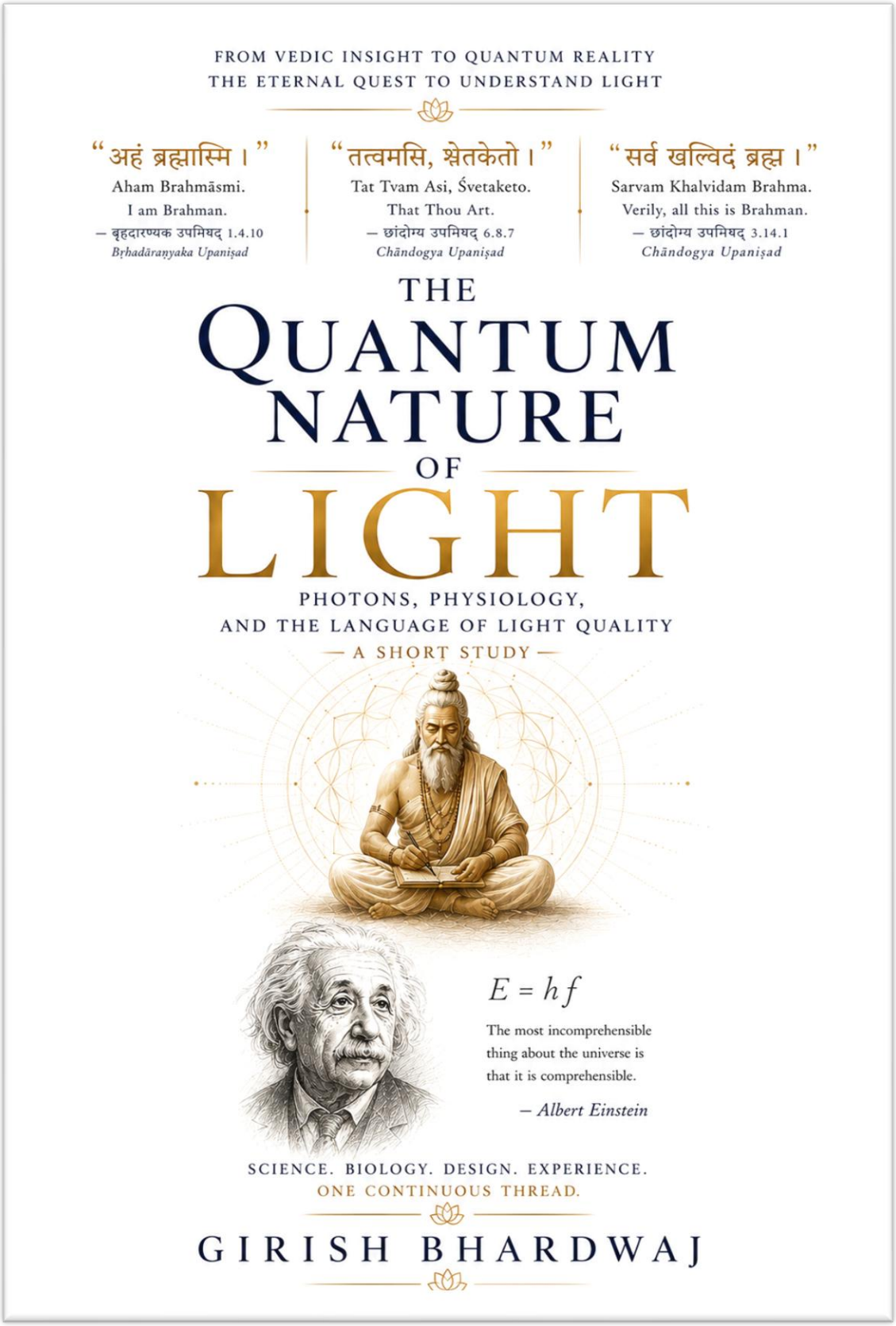
FROM VEDIC INSIGHT TO QUANTUM REALITY
THE ETERNAL QUEST TO UNDERSTAND LIGHT
"अहं ब्रह्मास्मि ।"
Aham Brahmāsmi.
I am Brahman.
— बृहदारण्यक उपनिषद् 1.4.10
Bṛhadāraṇyaka Upaniṣad
"तत्वमसि, श्वेतकेतो ।"
Tat Tvam Asi, Śvetaketo.
That Thou Art.
— छांदोग्य उपनिषद् 6.8.7
Chāndogya Upaniṣad
"सर्वं खल्विदं ब्रह्म ।"
Sarvam Khalvidam Brahma.
Verily, all this is Brahman.
— छांदोग्य उपनिषद् 3.14.1
Chāndogya Upaniṣad
THE
QUANTUM
NATURE
OF
LIGHT
PHOTONS, PHYSIOLOGY,
AND THE LANGUAGE OF LIGHT QUALITY
— A SHORT STUDY —
E = hf
The most incomprehensible
thing about the universe is
that it is comprehensible.
— Albert Einstein
SCIENCE. BIOLOGY. DESIGN. EXPERIENCE.
ONE CONTINUOUS THREAD.
GIRISH BHARDWAJ

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The Quantum Nature of Light Photons, Physiology, and the Language of Light Quality

Girish Bhardwaj

A Short Study
LIFE DID NOT BEGIN AT MY BIRTH, NOR SHALL IT END WITH MY DEPARTURE.
ALL THAT MATTER IS THE CONTRIBUTION DURING THIS JOURNEY OF ETERNAL ABODE.

A curious mind like a child researching circadian science, light–physiology relationships, quantum mechanics and light quality

Preface

This study began with a simple question: what physically happens when light strikes a surface, an eye, or a molecule? **It grew into an exploration linking the quantum behaviour of a photon—and other particles that often defy classical intuition, including our understanding of gravity—to the everyday language of lighting specifications.**

It is written *for the readers who are comfortable moving between registers: from Planck's constant to melatonin suppression to a colour rendering index, without treating any one of them as the 'real' subject and the others as decoration.*

That comfort with crossing registers is what makes this inquiry worth pursuing in the first place, and it is very much in the spirit of my own research- moving between circadian biology, the physiology of light, and the technical architecture of a **Light Quality Index** with the same curiosity a physicist brings to a photon.

The chapters that follow are deliberately short. Each is meant to be read in one sitting, and each ends where the next naturally begins: quantum optics hands off to retinal physiology, physiology hands off to a working index of light quality, and that index, in turn, is shown to be nothing more- and nothing less- than physics translated into design language.

1) Light as a Quantum Object

Long before lighting design had a vocabulary of colour temperature and rendering indices, physics had already discovered that light itself refuses to behave like a simple continuous wave. It arrives in discrete packets — photons — each carrying a fixed quantum of energy, $E = hf$, where h is Planck's constant and f is the photon's frequency. This single equation is the seed from which the rest of quantum optics grows.

Einstein's 1905 explanation of the photoelectric effect made the case concrete: shining light on a metal surface only ejects electrons above a threshold frequency, no matter how intense the beam. Intensity simply means more photons arriving per second- it cannot substitute for the energy carried by a single photon. Each photon either has enough energy to do the job, or it does not.

Photons also display wave– particle duality. Passed one at a time through a double slit, each photon lands as a single point on a detector, yet across many photons an interference pattern emerges- as though each one interferes with itself. This duality is not a philosophical curiosity; it is the operating principle behind diffraction gratings, spectrometers, and the interference coatings used in modern optical filters.

A third property, easy to overlook in a lighting context, is that photons carry intrinsic angular momentum, or spin. At the macroscopic scale this shows up as polarization- the orientation of a light wave's oscillation. Polarization determines how light interacts with lenses, glare-control louvres, and certain photobiological receptors, making it a genuinely physical, not merely decorative, parameter of a light source.

Light is where quantum mechanics started, and it stays one of the clearest windows into quantum behaviour.

Photon light is quantized

Light isn't a continuous wave with arbitrary energy- it comes in discrete packets called photons. Einstein showed this in 1905 explaining the photoelectric effect: light hitting a metal knocks out electrons only above a certain frequency, no matter how bright the light is. That only makes sense if each photon carries energy $E = hf$ (h = Planck's constant, f = frequency), and a single photon either has enough energy to eject an electron or it doesn't. Brightness just means more photons, not more energy per photon.

Duality of the wave-particle

Light behaves as a wave (diffraction, interference- the classic double-slit pattern) and as a particle (photons hitting a detector one at a time). Send photons through a double slit one at a time, and each lands as a single point, but over many photons an interference pattern builds up- as if each one interferes with itself. This is the core weirdness quantum mechanics had to formalize.

Quantization of atomic energy

Atoms absorb and emit light only at specific frequencies because electrons occupy discrete energy levels. A photon is absorbed only if its energy exactly matches the gap between two levels ($E = \Delta E$). This is why atomic spectra look like sharp lines, not a smooth rainbow- and it's the basis of spectroscopy, lasers, and LEDs.

Photons spinning and polarisation
Photons carry intrinsic angular momentum (spin 1), which shows up macroscopically as polarization. Entangled photon pairs- correlated in polarization even when separated- are the standard testbed for Bell's theorem experiments, which confirmed quantum mechanics can't be explained by hidden local variables.

Where this touches my paper and some practical research work: Physiology, Plabnts, lighting parameters visible as well as non visible, lighting design and the neurosciences.

On the substance: this is a popular comparison people draw, but it's worth being upfront that most serious physicists and Indologists see it as a loose analogy rather than a real convergence.

A few genuine points of resonance people point to:
Non-duality and observation: The Upanishadic idea that consciousness (Atman) isn't separate from ultimate reality (Brahman) gets compared to the observer effect in quantum mechanics, where measurement seems to affect the state of a system.

Maya and superposition: Some draw a parallel between the Upanishadic concept of maya (the world as appearance rather than fixed substance) and superposition (a particle existing in multiple states until measured).

Interconnectedness: Upanishadic monism ("all is one") echoes quantum entanglement, where particles remain correlated regardless of distance.

Where this breaks down: quantum mechanics is a precise mathematical formalism describing measurement outcomes and probabilities, not a statement about consciousness or metaphysics.

Light-as-metaphor territory there is actually a richer vein specifically around light in the Upanishads (the "light of consciousness," Brahman as self-luminous) that has connected more to my work with the quantum angle.

The core motif: Brahman as self-luminous

The Upanishads return again and again to light as the primary metaphor for consciousness and ultimate reality not light as emitted from something, but light as self-revealing. The key phrase across several Upanishads is that Brahman is "svayam-jyoti" self-luminous, requiring no external source to be known, the way the sun needs nothing else to be seen but by which everything else is seen.

A few specific threads worth knowing:

Mundaka Upanishad: has the famous verse describing the sun, moon, stars, and fire as all reflecting the light of Brahman — "by his light all this shines" (na tatra sūryo bhāti). The implication: physical light is a metaphor pointing to something prior to it- awareness itself as the condition for anything, including light, to be perceived at all.

Brihadaranyaka Upanishad: has a passage on "what is the light of man" asking what a person sees by after the sun sets, the moon sets, the fire goes out. The answer moves progressively inward: speech, then mind, then finally Atman - the self as the last, irreducible light.

Chandogya Upanishad: uses light imagery for the atman residing "within the heart," described as smaller than a grain and yet containing all worlds - light as scale-defying, not bound by physical dimension.

The quantum comparison borrows scientific authority it hasn't earned. This one doesn't need to borrow anything- it's light functioning as the original metaphor for consciousness in the Indian tradition, which is a much stronger and more defensible editorial claim:

Bespoke lighting design sits at the tail end of a metaphysical lineage where illumination and awareness were never separate concepts to begin with.

That's a real intellectual thread you can pull without over-claiming physics.

Architected editorial framework balancing tone, typography, and philosophical depth

Svayam-Jyoti: On Light That Needs No Source - The Original Metaphor"

In my upcoming news channel – The Bureau of Lighting Voice TBLV's editorial length being summarised here:
Open concrete, not philosophical. Start with a physical fact about light — the eye's relationship to the sun, or the strange property that you can't see light itself, only what it touches. Ground the reader in sensation before you go abstract. TBLV pieces that open with metaphysics lose people in the first paragraph.

Introduce the Upanishadic move as a historical/textual fact, not a claim you're endorsing. Something like: "Three thousand years before anyone in this office"- you're reporting on a tradition, not proselytizing it. This is what keeps it credible rather than mystical-adjacent.

The pivot: from Brahman-as-self-luminous to the actual design problem- that all lighting design is really an argument about what needs revealing versus what reveals itself. A well-placed fixture disappears; a badly-placed one becomes the subject instead of the room. That's your bridge from ancient text to studio practice, and it's honest

Note:
Refer the Upanishads as precedent, not proof. The moment the piece implies "and that's why our lighting is spiritually significant," it curdles into the kind of luxury-adjacent mysticism your tone guide already rejects.

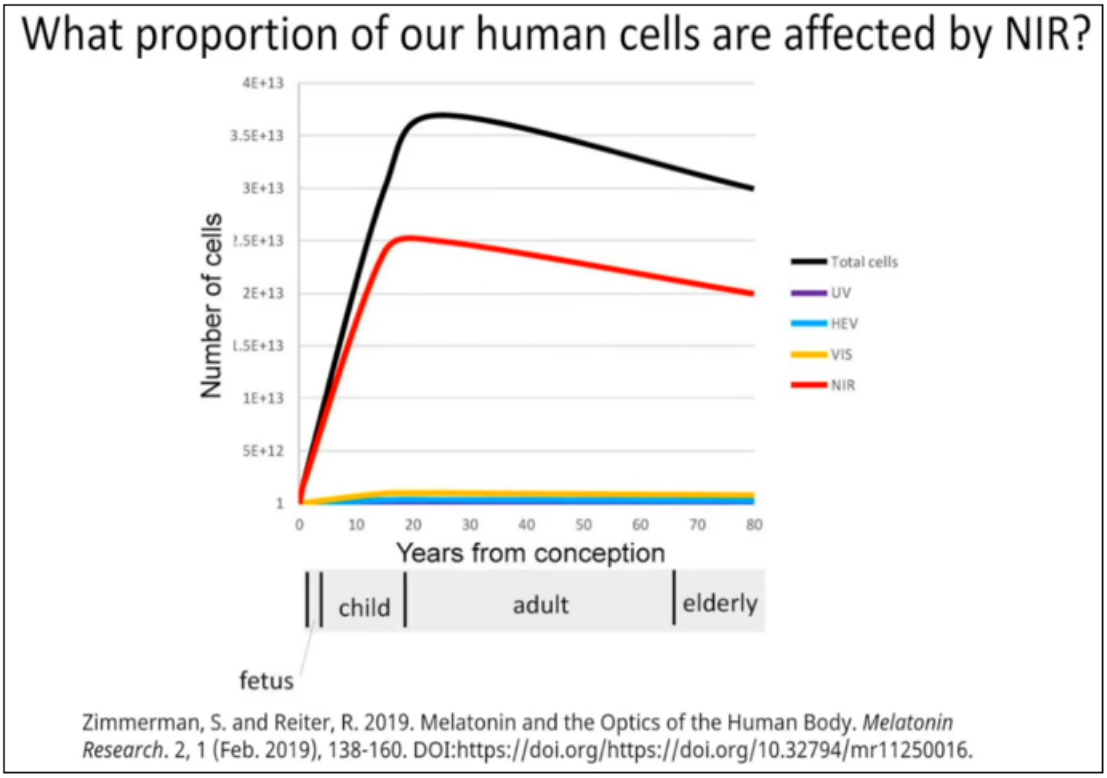
2) Light and Human Physiology
Quantum behaviour does not stay confined to the optics bench - it governs how light interacts with biological tissue as well. Every photon absorbed by a photoreceptor triggers a discrete photochemical event: a single quantum of energy

reconfigures a molecule, which in turn initiates a nerve signal. Vision, and much of human photobiology, is built on this quantized exchange between light and matter.

Beyond the rods and cones that build a visual image, the retina contains a third class of photoreceptor: intrinsically photosensitive retinal ganglion cells, or ipRGCs, containing the photopigment melanopsin. These cells respond most strongly to short-wavelength light around 480 nanometres- the blue-cyan band- and they do not contribute meaningfully to what we consciously see. Instead, they report ambient light levels directly to the suprachiasmatic nucleus, the brain's master circadian clock.

This is the physiological basis of the circadian effect of light. Morning exposure to blue-enriched light suppresses melatonin production and reinforces wakefulness; warm, low-melanopic light in the evening allows melatonin to rise, supporting sleep onset. The timing, spectral composition, and intensity of light exposure across a day therefore act as a biological signal, not merely a visual one- a distinction now central to human-centric lighting design.

Because this pathway responds to spectral composition rather than illuminance alone, two light sources with identical lumen output can produce very different circadian effects depending on how their photon energy is distributed across wavelength. This is precisely the gap that visual metrics like lux and lumens were never built to describe.



Zimmerman, S. and Reiter, R. 2019. Melatonin and the Optics of the Human Body. *Melatonin Research*. 2, 1 (Feb. 2019), 138-160. DOI:https://doi.org/https://doi.org/10.32794/mr11250016.

3) Light Quality Index- Reading the Full Photon

A Light Quality Index attempts to describe a light source the way physics actually describes a photon: not by a single brightness number, but by a fuller set of visible and invisible parameters. Two broad categories are useful to separate.

From the research work, light therapies, experiments, implementations, going through various research platforms, books, journals and the relevant courses. (Girish Bhardwaj- www.girishbh.om)

Bit confused as to what is LQI? Never heard of it?

Before we delve into this, let us acknowledge once again, that why light is important to us?

It's been more than 200 years the human beings are subjected to the world of artificial lights, yet a common person's knowledge is far from the real world of this subject – THE LIGHT. Out of these 200 years the maximum time has been spent under the fluorescents by the urban population as compared to past one decade with LEDs)

As I am writing this article, one of the repetitive question asked by many (including architects, PMCs, lighting enthusiasts, interior designers and the occupants) to me is, that how light as a zeitgeber influences the molecular mechanism are sensing the environment for the time cues? How circadian is disrupted or aligned, what is the connection between immune system and light, why there are chances of being prone to some types of cancer-with relation to light, how retina gets damaged, effects of white LED exposure on retinal pigment epithelium, relationship of metabolism and muscular atrophy with respect to light and many of these inquisitiveness.

The fact and the answer is that there has been thousands of researches and the establishments of researches, but most of the human beings are unaware or have lack on subject (including the people from lighting fraternity), as they have not undergone in depth towards the relationship between

physiology and light which is so true to be criticized or ignored. I for one have no doubts now after going through this over the past six years.

The idea that there can be an "unambiguous technique" for human-bio favorable lighting like tunable white with the absence of other non-visible and visible parameters is totally unrealistic, because of the tremendous variability between individuals based on their age, genetics, environmental factors, individual physiology, eating habits, and wake up or the sleep timings and our behavioral aspects.

The harmony of the glands is accomplished by constantly synchronizing our body's atoms, glands, genes, molecules, cells hormones in alignment of time cues- the LIGHT.

Being tenacious and ascertaining a healthier lighting space always requires a process of trading off some aesthetical and volumetric aspects of the space for healthier future gains.

However, this has been a very thick proposition from an architectural and interior point of view, especially in the office and the residential segments.

We need to strategies w.r.t. legislative to be proposed and implemented regarding ILQI-INDOOR LIGHT QUALITY INDEX., as there is an exponential rise in severe neuro and retinal disorders as well as the related illnesses. This is due to the inappropriate forms and sources of light that are contributing negatively to our health are:

- Retinal damage
- Brain fatigue
- Stress
- Migraine
- Insomnia
- EFD
- Cancer
- Obesity
- Age related Macular degeneration
- Skin diseases

As compared INDOOR AIR QUALITY, INDOOR LIGHTING QUALITY IS EQUALLY ESSENTIAL TO GUAGE.

We are being misled in the name of Human centric lighting, tunable circadian lighting in a very absurd and unethical ways, The greed and the unawareness of hazardous factors we are being played with respect to our physiological parameters levied by our body (Our body is not a machine but an assembly of molecules- Seven trillion trillion trillion toms and 89 billion neurons)

The inclusions and the audits of these inclusions of healthy parameters of lighting like IRC*-IRB*-IRA*-Mitochondrial and other related benefit, The mimic of Blue, Bluish white and Bluish grey sky- limbic ways and psychological benefits / low energy dissipation / luminance balance, Inclusion of UVA* Solitrol activation etc. is must apart from industry specific and guidelines like: Percent Flicker (IEEE Std 1789-2015, IES: RP-16-10, CIE: TN-006) / Flicker Index (IEEE Std 1789-2015, IES: RP-16-10, CIE: TN-006) / Pst LM Short Term Flicker Severity (CIE: TN-006, IEC TR 61547) / Full CIE S 026:2018 metrics / Blue pump/accordance wavelengths & red pump accordance wavelengths / PAR PPFD µmol/m2/s / Ratio functions, e.g. red/F far red / Programmable weighting functions / Melanopic irradiance / TM-30 parameters

What is Visible light?

Light is electromagnetic radiation within the portion of the electromagnetic spectrum that can be either perceived or might not be perceived by the human eye. Light sometimes refers to electromagnetic radiation of any wavelength, whether visible or not. In this sense, gamma rays, X-rays, microwaves and radio waves are also light.

Light exerts physical pressure on objects in its path, of velocity, wavelength & frequencies. (There is a definite process of thermodynamics in the light.)The photon is a type of elementary particle. It is the quantum of the electromagnetic field including electromagnetic radiation such as light and radio waves, and the force carrier for the electromagnetic force.

Light is the Governor of the Universe and the Molecular Mechanism

Misconceptions about light.

The biggest misconception about light is that we only believe that light means he visible spectrum which has no physiological effects. For example X ray is the form of light which has advantages though getting an application of imaging, but at the same time too much exposure to X rays can lead to DNA rupture, cancer etc. Similarly with UVB/UVC.

On the other hand the IRB or NIR, FIR or IRC are very much beneficial for human being and many creatures. The existence of light starts from the cosmic ray, gamma rays, X rays, UV, VIBGYOR, NIR, FIR, Microwaves. Radio waves and the broadcast waves

Why is natural light important

Let's reveal the benefits of the Natural light – The sunlight Immune system: The immune system boost up when we are exposed to the sunlight but not too much of exposure. The presence of near infra-red and infra-red light waves strengthens and boosts our immune system.

Good for Bones: Our bones need lot of Vitamin D and it's the SUN which can help in an enormous way to impart vitamin D. The presence of UVA (Ultraviolet-A) imparts Solitrol which is also known as the Sun hormone.

Alignment of our sleep: The sleep and the wake cycles are governed primarily by the light and most importantly by Sunlight. The alignment of our circadian rhythm is totally dependent on the sunlight.

Energy production: MITOCHONDRIA, in these we have specific molecule known as Cytochrome C oxidase, which is responsible to produce energy within MITOCHONDRIA. This means Adenosine Triphosphate (ATP), which is the end product of energy correlation and is the fuel our cells need for

transporting irons for metabolism. If ATP production is stopped, we can die in 15-20 seconds. Our body produces 30-100 KG of ATP in 24 hours depending upon our weight, height, age etc. The other hidden fact is that only 1/3rd part of the energy in our body comes from the food rest 2/3rd comes from the radiations and the light, and especially the Sunlight.

What Is LQI?

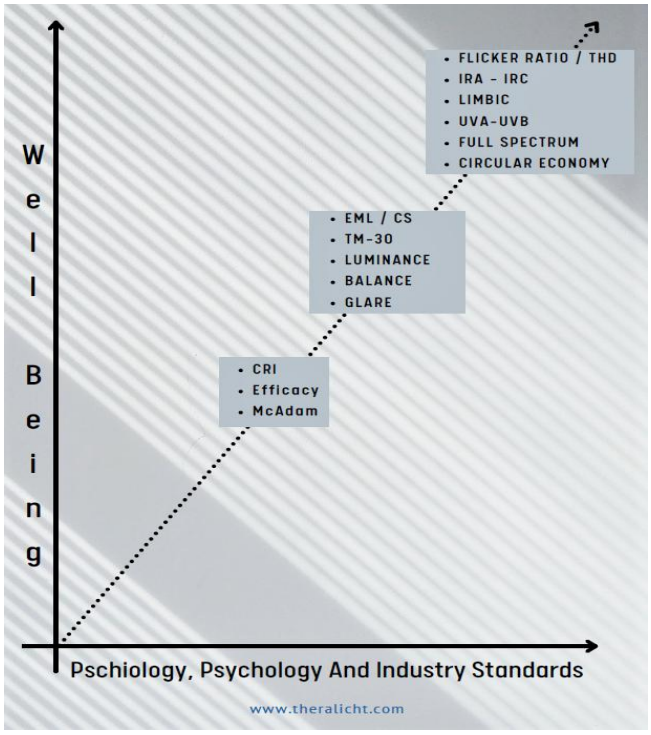
The LQI is the term coined by me, after being fed up by witnessing the AQI-Air Quality Index, WQI-Water Quality Index. It was a clear indication that most of the human beings are unaware on the subject LIGHT and taken the light for granted as a subject.

There are many levels of complexities and understandings (Physiological point of view and light as a subject, thus our involvement with physiology and psychology as subjects are very important and must not be ignored or avoided.

Thus the quality parameters in the environment where the light is subjected (especially in the offices, homes and on the roads) are from physiological based rather only industry standards like lux levels, Rg, Ra, CRI, MacAdam, T1/T2, EML Lumens, efficacies etc.

How does the LQI works?

The DNA of our lighting industry changed with the arrival of LEDs. Thus our parameters w.r.t. the biology has to be restructured. The LQI primarily works on the contribution of lighting parameters (visible and non-visible) on human (the occupants) physiology and the psychology.



What do the LQI values mean?

The purpose of the LQI is to help you understand what Light Quality is contributing to our health. **For example:**

As NIR light photons reach these molecules, this stimulates the cells' mitochondria (colloquially termed the "power generators" of cells) to produce more adenosine triphosphate (ATP), which fuels cellular energy production. This, in turn, energizes all cells irradiated by the light

To make it easier to understand, the LQI is divided into DIFFERENT levels of health concerns like

a) Effects of different spectrums on human health
b) By an appropriate use of lighting controls, tunable white light blending with biored* and bioblue* lights to induce replica of the nonvisible and visible parameters of light { dawn, full sunny day & dusk timelines.}
c) Combination of appropriate forms of LEDs.
d) Avoiding the direct view of light sources, incorporating a lighting design to reduce the number of lights in a pragmatic manner.
e) Allowing the maximum parameters of Sunlight through the glass enveloped buildings

And many like these….

What is unhealthy light?

I would like you all to recollect and hold on to one fact that the DNA of LIGHT has changed with the arrival of LEDs. Previously light was in the form of heat energy but now it's not.

Thus, as the DNA has changed, so our way of approach on managing the parameters of light must change as well. We have to brainstorm and reinvent the thinking process, to better our obsolete methods of lighting consultancy and offer the best to the users (office goers, residences, hospitality & health care).

As we are spending more than 90% of our times in the indoors, it is essential to know that general the emission of short wavelength produced by LEDS from computer screens, smartphone, television, and tablet screens apart from the general lighting fixtures (exceptions are always there) for our homes and workplaces are giving rise to many disorders like sleep disorder, migraine, insomnia obesity, retinal damage, brain fatigue and many.

The continuous triggering of cortisol is detrimental as not only it hampers the immune system but also resulting in our bullied behaviors.

What are the health effects?

The severe disorders and the illnesses the inappropriate forms and sources of light that are contributing negatively to our health are:

- Retinal damage
- Brain fatigue
- Stress
- Migraine
- Insomnia
- EFD
- Cancer
- Obesity
- Age related Macular disorder
- Skin diseases

One of the examples (As many of us are aware and struggling in our daily lives)

Sleep: Sleep is the form of the paybacks to be fatigues of mind and body working throughout the day. Light is the only source which can disrupt the sleep wake cycle known as circadian rhythm? The Intrinsically photosensitive retinal ganglion cells [ipRGC] communicates information directly to SUPRACHIASMATIC Nucleus that forms our biological clock mainly responsible for our CIRCADIAN RHYTHM. A central circadian clock, located in the suprachiasmatic nuclei (SCN) of the hypothalamus, through negative Transcription-translation feedback loop (nTTFL),

The improper forms of LEDs (whether the product or the way these are installed) are giving us migraines, retinal fatigue and many other disorders. Nevertheless LEDs have far more advantages too. (Again I am referring to office, healthcare and residential lighting sector only)

Making invisible visible with defined parameters and indicators. The solution:

Holistic approach LQI (Office luminaires)

Key Indicators			Type of lighting fixtures and its benefits		
Sl.No	**Objectives**	**Parameters**	**Conventional**	**HCVL**	**Salvation Series- CAMA*-By Girish Bhardwaj / Tashi Agarwal- PATENT**
1	Illuminance	Lux levels Vertical and Horizontal (Balance)	√	√	√
2	Efficiency	(Total cost of ownership a)TCO & CBA (Cost Benefit Analysis)	√	√	√
3	Maintenance	Repair	√	√	√
4	Rejuvenation	Feel good factor (limbic)		√	√
5	Visual Acuity	Actual and perceived illuminance-luminance balance		√	√
6	Psychological need address	Connected to the dynamics of nature		√	√
7	Adherences to the industry standards	EML, CS, TM-30, IEC, IEEE, ASHRAE-RP, ANSI RP, IES-EB10,		√	√
8	Personal User intervention	Lux, Lumens, CCT etc		√	√
9	Health benefits	Addressing: Retinal fatigue, brain fatigue, Migraine etc			√
10	Physiological need address	Immunity, ATP, Mitochondria boost, Homeostasis			√
11	Overall Wellbeing	Physiologically stable and Biophilic factor			√
12	Circadian and Sleep	Rhythmic alignment and Sleep disorder management			√
13	Diurnal adaptation	Precise bio wavelength for healthy lighting parameters eg precise IRB/IRC radiations			√
14	Circular economy	Repair, refurbish, Longevity of the product, Reusable components, and biodiversity pro (TM-CIBSE)			√

A food for thought:
The fluorescents were so easy to recycle (though there were certain protocols). They had good UV in them, they had a better version of balancing luminance / illuminance. Whereas LED waste easy so carcigenous and land filling which is against circular economy.

However, my point is that, we still have places where we can use fluorescents and incandescent lamps which are very beneficial for human physiology and our circular economy. Though there are now several organizations who are working on these parameters like NIR and F through LEDs.

We need to balance the demands and the design between LED, Fluorescent and incandescent lamps. No one is going to be crucified, no one should be ashamed of specifying the combination of these. Let's give it a try not only for our biological benefits but also to contribute in circular economy, saving bio diversities.

4) Closing Summary: Physics to Physiology to Design
The through-line across this study is a single idea: light is not a generic backdrop but a quantized, spectrally specific signal, and the human body- like a well-calibrated instrument- reads that signal at the molecular level. A photon's energy determines whether it can eject an electron in a photodetector or trigger a photopigment in the retina. Its wavelength distribution determines whether it renders a fabric's true colour or nudges a circadian clock forward. Its temporal

behaviour determines whether it is felt as steady illumination or as fatiguing flicker.

For anyone researching circadian science, light–physiology relationships, and the composition of a genuine Light Quality Index, the discipline required is the same discipline physics has always demanded of light: look past the single aggregate number, and ask what the underlying spectrum, timing, and quantum structure of the source actually are. My inquisitiveness — moving from quantum optics into circadian biology and back into a working index for light quality- traces exactly that arc, treating light as the layered, physically rigorous subject it is rather than a simple commodity of lumens per watt.

In brief, four ideas carry the whole study:

- Light is quantized- photons carry discrete energy (E = hf), not a continuous, arbitrarily divisible flow.
- The body reads light photochemically- ipRGCs and melanopsin translate spectral composition into the timing signal that drives the circadian clock.
- Brightness alone is an incomplete description- a genuine Light Quality Index needs both visible metrics (SPD, CCT, CRI/TM-30) and invisible ones (melanopic content, UV, IR, flicker).
- Good lighting design is applied physics- every spec-sheet number ultimately traces back to the behaviour of a single photon. They also must include TAIR, MRSE and PBI from SLL and CIBSE.

A rigorous Light Quality Index, in this sense, is not a departure from physics. It is physics translated into a design vocabulary- one photon parameter at a time.

A brief journey from the photon to the physiology it moves- and finally to the vocabulary a Light Quality Index needs to describe both. Written as a companion piece to an ongoing inquisitiveness into circadian science, light–physiology relationships, light designs, the product portfolio and the true composition of light quality.

THE QUANTUM NATURE OF LIGHT