PRINCIPAL RESEARCH

1.) Fundamental investigations in high speed laser diodes for fiber-optic telecommunication –

Basic investigations of laser modulation dynamics yielded a simple analytic relationship that clearly captures the roles played by three independent, fundamental device and material parameters of the laser diode [i. - iii.] (see **PRINCIPAL PUBLICATIONS** below.) This simple relationship facilitates engineering of laser diodes that can be directly modulated at high data rates by optimization of each of the three parameters individually. This approach led to the first realization of a laser diode with a direct modulation bandwidth exceeding 10GHz [iii.]. It also pointed clearly to the important role of quantum confinement of carriers in the laser medium in achieving high speed laser diode operation [ii.,iv.], thus providing impetus for introduction of quantum-engineered materials for high speed laser devices. Today, directly modulated quantum-well (QW) and strained-layer QW laser diodes constitute the engines of all high speed fiber-optic transmitters in local area and metropolitan fiber-optic networks. This work also pointed the way to further developments with advanced lasers incorporating quantum wires and dots, an area that is now poised for high impact for the same reasons.

2.) Development and field deployment of ultra-stable RF-over-fiber (RoF) systems for syntonization and synchronization of NASA's antennas and planetary imaging radars at the worldwide Deep Space Network (DSN) complexes –

Development of ultra-stable RoF networks at the NASA Jet Propulsion Laboratory leading to their deployments at NASA's worldwide DSN complexes underpinning interplanetary spacecraft communications and tracking operations critical to all deep space exploration missions and planetary radar imaging operations undertaken by NASA in the past 30 years[v.]

3.) Hybrid Fiber Coax (HFC) access networks –

HFC is the infrastructure underpinning cable-modem TV and internet access to the home. The majority of fiber links in in HFC networks are RoF links using high linearity laser-diode transmitters modulated by multiple subcarriers. While at Ortel Corp. during the 1980s, Prof. Lau experimentally investigated fundamental limits in RF distortion characteristics of laser diodes directly modulated by multiple subcarriers, measurements were found to closely match results predicted from fundamental distortions generated by stimulated emission – the very mechanism underpinning lasing action [vi.], thus this distortion limit is fundamental and cannot be circumvented by clever device structure design. This finding, together with results from investigations of interferometric noise generated by double Raleigh backscattering in long fiber links [vii.], provided impetus for development and introduction of commercial high performance RF-over-fiber systems using the now widely employed DFB laser transmitters incorporating pre-distortion linearization circuits and high isolation optical isolators. Ortel's transceiver products are widely deployed in Hybrid Fiber Coax (HFC) networks today on which CATV services and cable-modem internet access to homes and offices depend.

4.) Wireless access infrastructures in dense urban and campus environments –

Development of a RoF-based Distributed Antenna Systems (DAS) for coverage and capacity enhancement in challenging radio environments inside concrete-rebar buildings and underground structures in urban areas [viii.] Commercialized versions of this RoF-based DAS system by LGC Wireless, Inc., (co-founded by Prof. Lau) are deployed today for wireless coverage in high traffic areas inside buildings and campus arenas in > 50 countries on every continent thus establishing itself as a de-facto industrial standard.

PRINCIPAL PUBLICATIONS

[i.] Lau, K. Y., Bar-Chaim, N., Ury, I., Harder, C., and Yariv, A., "Direct amplitude modulation of short cavity GaAs lasers up to X-band frequencies," Applied Physics Letters, 43 (1), 1-3, 1983 – *Identification of the fundamental laser parameters governing direct modulation bandwidth.*
http://authors.library.caltech.edu/9801/1/LAUapl83a.pdf

[ii.] Lau, K. Y.; Harder, Ch.; Yariv, A., "Direct modulation of semiconductor lasers at f > 10 GHz by low temperature operation," Applied Physics Letters (ISSN 0003-6951), vol. 44, Feb. 1, 1984, p.273-275. - *Definitive experimental verification of the explicit dependence of the modulation bandwidth on differential optical gain (an intrinsic material parameter – basis of quantum well and strained quantum well laser diode designs prevalent in fiber-optic networks today.)*
http://authors.library.caltech.edu/9807/1/LAUapl84a.pdf

[iii.] Lau, K. Y.; Bar-Chaim, N.; Ury, I.; Yariv, A.; "11-GHz direct modulation bandwidth GaAlAs window laser on semi-insulating substrate operating at room temperature," Applied Physics Letters, vol.45, Aug.15, 1984, pp. 316-318. – *Demonstration of direct modulation bandwidth of laser diodes at f >10GHz - figurative equivalence of 4-minute mile for high-speed lasers*
http://authors.library.caltech.edu/9817/1/LAUapl84c.pdf

[iv.] Arakawa, Y., Vahala, K.,Yariv, A., Lau, K., "Reduction of the spectral linewidth of semiconductor lasers with quantum wire effects - spectral properties of GaAlAs double heterostructure lasers in high magnetic fields," *Applied Phys. Letters*, Volume: 48, Issue: 6, 1986, Page(s) 384 – 386. *Demonstration of enhancement of differential optical gain by quantum confinement of carriers in a magnetic field, leading to enhancement of modulation speed and reduction of spectral linewidth*
http://authors.library.caltech.edu/1735/1/ARAapl86.pdf

[v.] Kam Y. Lau, George F. Lutes and Robert L. Tjoelker, "Ultra-stable RF-over-Fiber Transport in NASA Antennas, Phased Arrays and Radars [*Invited*]," *IEEE J. Lightwave Technology*, Volume 32, Issue 20, Page(s): 3440 - 3451, Oct., 2014. *– Review of RF-over-fiber transfer of ultra-stable frequency and timing signals critical for operations of NASA's Deep Space communications and tracking antenna networks, ground based and space borne planetary imaging radars.*
http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=6776389

[vi.] Lau, K. Y.; Yariv, A.;"Intermodulation distortion in a directly modulated semiconductor injection laser," Applied Physics Letters, vol. 45, Nov. 15, 1984, p. 1034-1036. – *Experimental and analytic studies of third-order intermodulation distortion in directly modulated laser diodes, leading to understanding of the fundamental nature of the distortion.*
http://authors.library.caltech.edu/9847/1/LAUapl84e.pdf

[vii.] Lau, K. Y.; Gee, C.M.; Chen, T.R.; Bar-Chaim, N., Ury, I; "Signal-induced noise in fiber-optic links using directly modulated Fabry-Perot and distributed- feedback laser diodes,".; IEEE Journal of Lightwave Technology, Volume: 11 Issue: 7, July 1993, pp. 1216-1225 – *Discovery and mitigation of a new type of noise of importance in and unique to field- installed linear (RF) lightwave transmission systems*.
http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=238084

[viii.] Kam Y. Lau, "RF Transport Over Optical Fiber in Urban Wireless Infrastructures [Invited]," J. Opt. Commun. Netw. Volume 4, Issue 4, Page(s): 326 - 335, April, 2012. – *Overview of current commercial deployment of RF-over-fiber transport in urban wireless networks.*
http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=6180278&tag=1