DEMONSTRATION OF FREE-SPACE OPTICAL COMMUNICATIONS

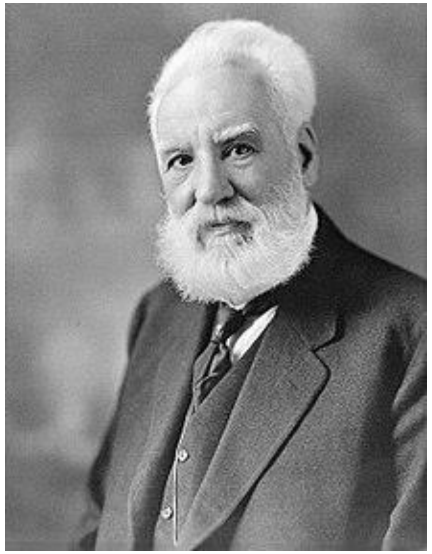
Narkis Shatz, Mark Squire
SureFire, LLC
Contact email: nshatz@surefire.com
http://aron.surefire.com

Narkis Shatz, Ph.D.

Narkis Shatz is one of the inventors and program lead of the Augmented Reality Optical Narrowcasting (ARON) technology for SureFire, LLC. Dr. Shatz's special interests are in computational physics, methodologies for inverse engineering and nonimaging optics. Dr. Shatz was a Chief Scientist with Science Applications International Corp. for 26 years. He has authored dozens of papers on nonimaging optics and holds 30 patents with his fundamental contributions in this area internationally recognized. Much of his work was as a program manager on DARPA-funded optics programs.

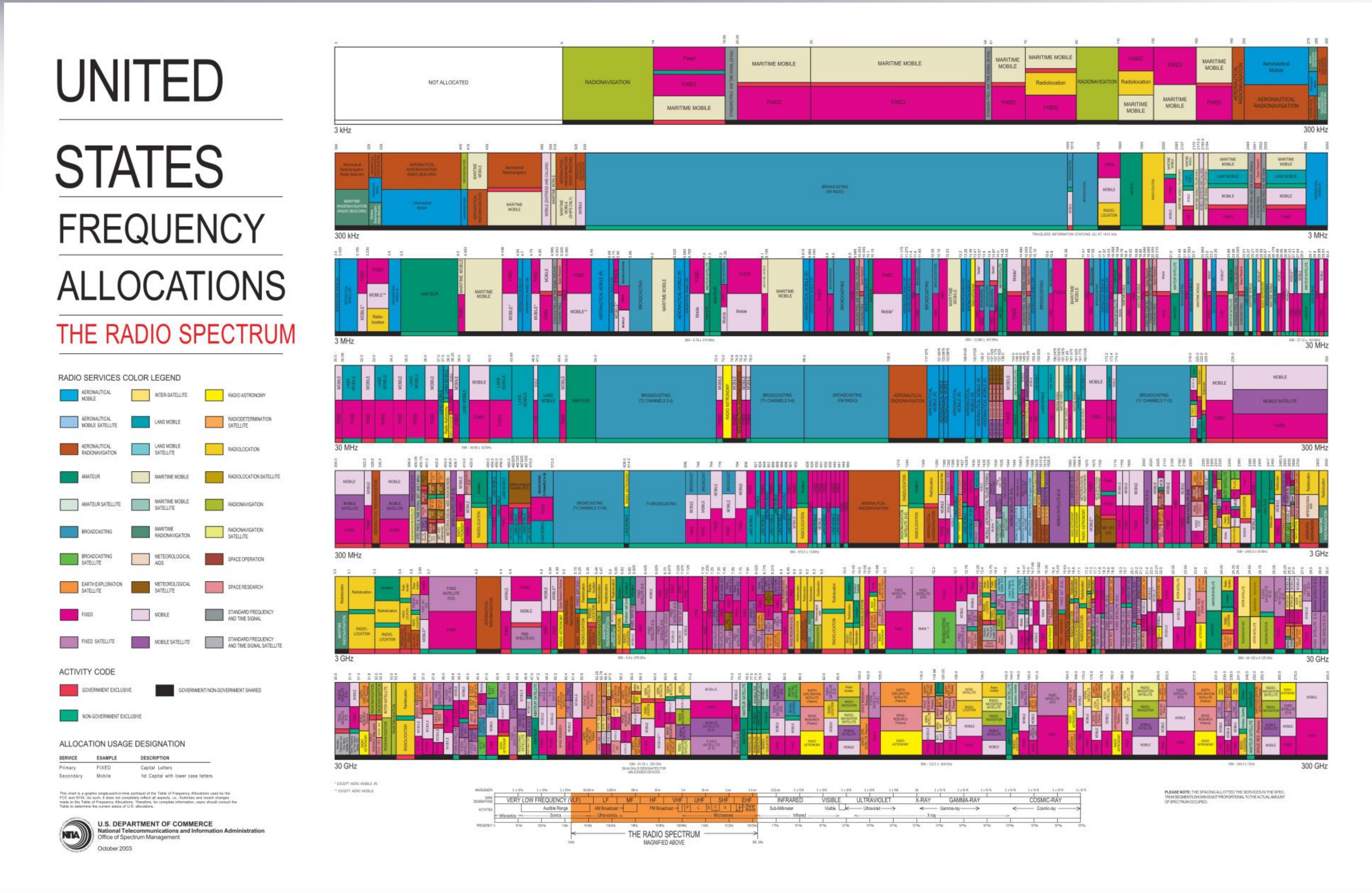
Historical Background

Free-Space Optical Communication was invented and demonstrated by Alexander Graham Bell in 1880 (19 years before radio).



Bell believed the photophone's principles were his life's "greatest achievement", telling a reporter shortly before his death that the photophone was "the greatest invention [I have] ever made, greater than the telephone".

Radio waves frequency allocation by the FCC (3 Hz - 300 GHZ)



Physics of Optical vs RF wavelength communications

Electromagnetic waves do not interfere with each other during propagation.

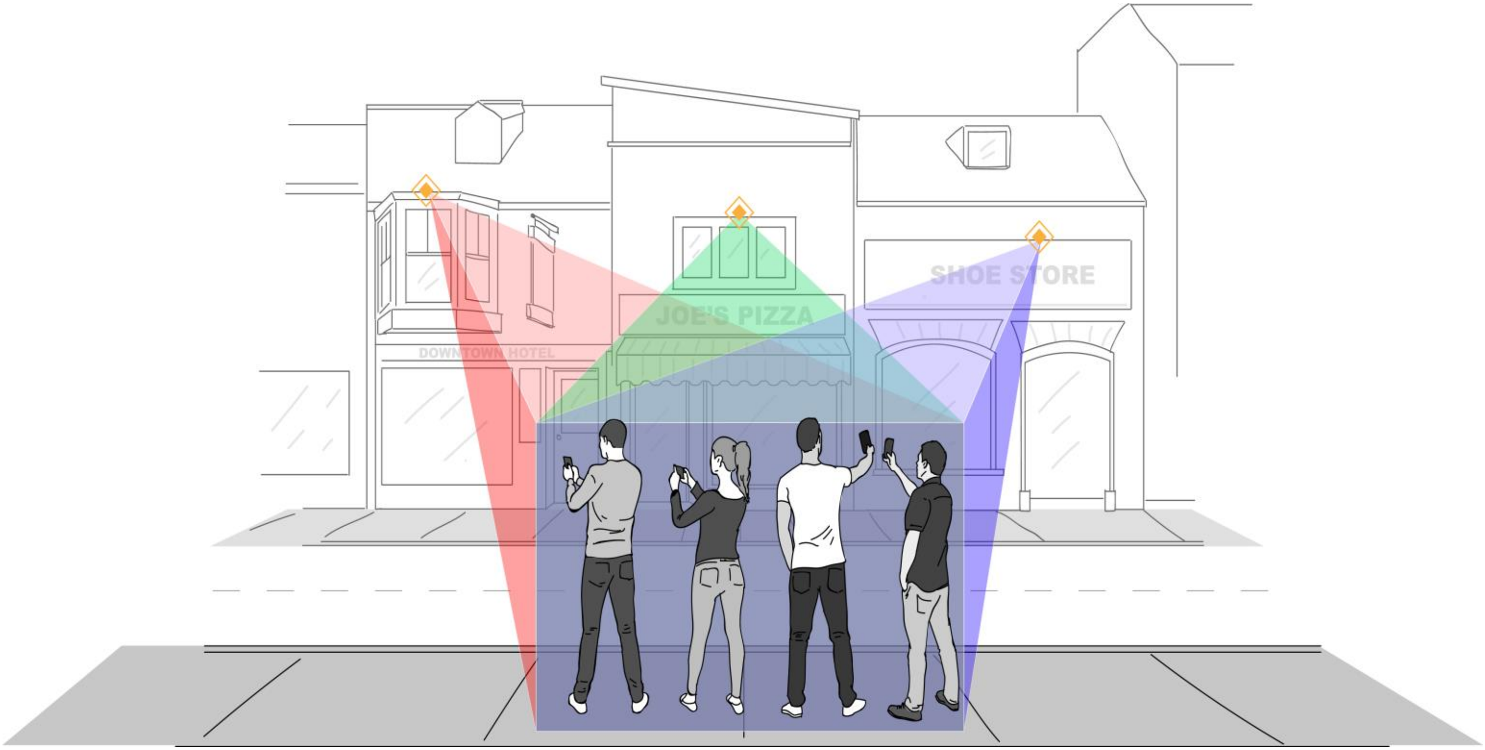
RF Signals	**Signals can turn corners and can penetrate many materials.**	**Require a carrier wave to induce an AC current at the antenna.**	**Multiple signals at same wavelength result in jamming at receiver antenna.**
Optical Signals	Signals require line of sight and cannot penetrate most materials.	Signal is received on focal plane array of miniature photodiodes.	**Multiple signals at same wavelength can be received simultaneously.**

Why use free-space optical communications rather than RF?

- A unique and novel user experience that is a natural fit for the Smart Cities environment.
- RF facing spectrum crunch.
- Optical frequencies are unregulated and free.
- Higher data rates possible with optical (w/multiple signals).
- Optical more secure than RF.
- Cannot be jammed; can be used in photonic cross-fire mode.
- Particularly advantageous for mobile devices.
- Location & orientation sensing is superior to RF.

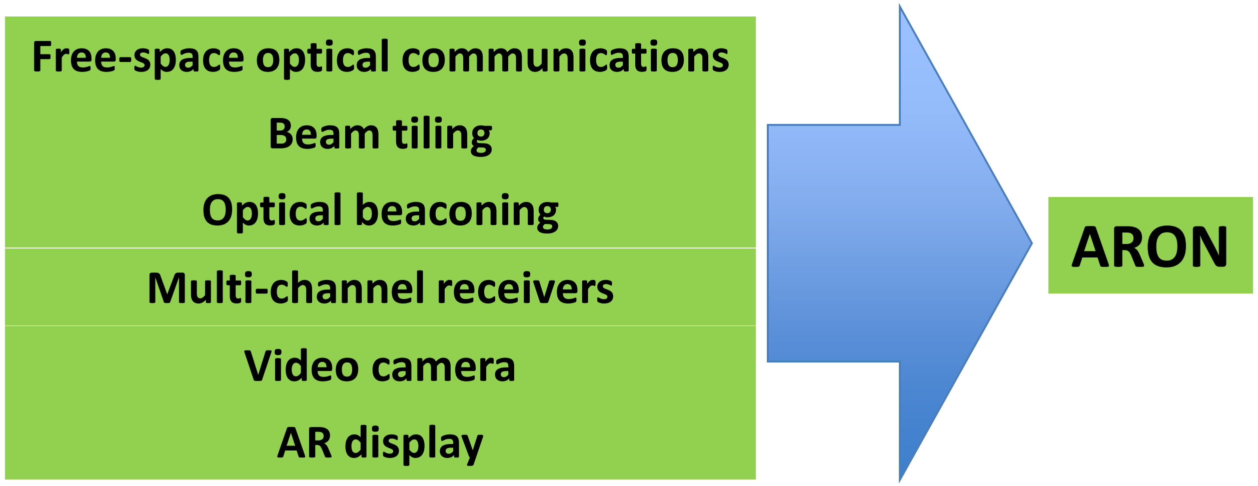
Augmented Reality and Optical Narrowcasting

- ARON augments human vision with data.
- Optical narrowcasting transmits information locally using beams of light with tailored directionality.
- ARON achieves a many-to-many network topology.

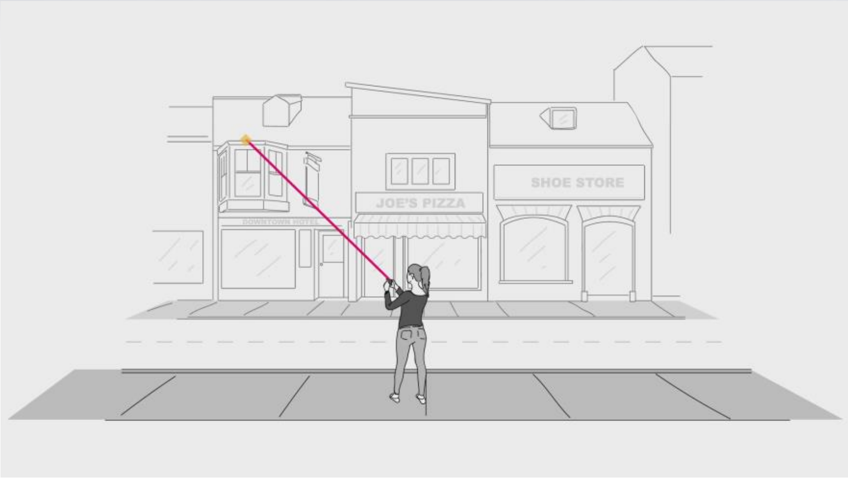


Augmented-Reality Optical Narrowcasting (ARON) elements

ARON is a pioneering technology that provides a robust many-to-many free-space optical communications channel for personal use with mobile devices.



Overcoming obstructions to line-of-sight with FEC, Swaths and Photonic Cross-Fire



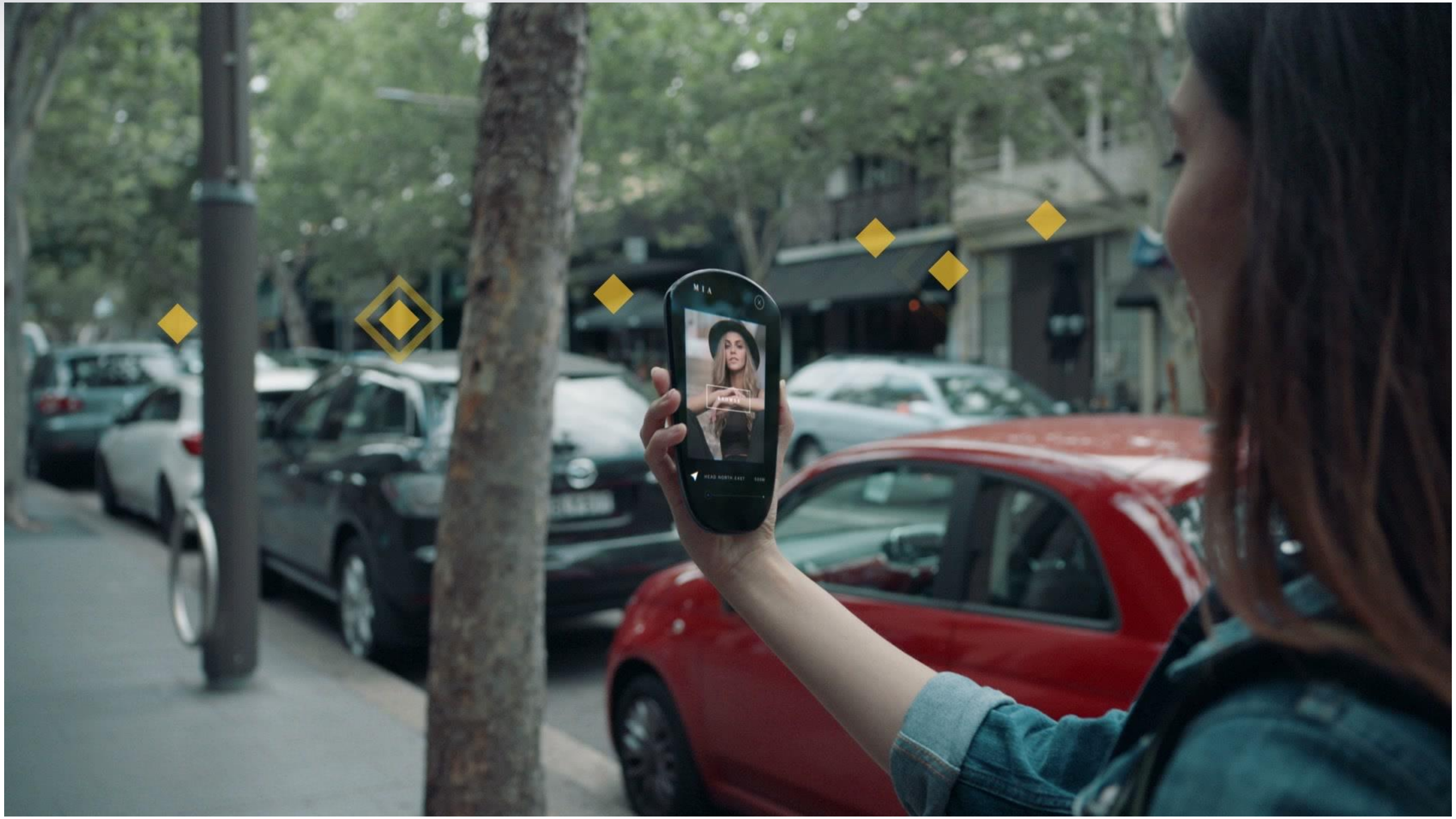
Forward error correction (buffering)

Expanding beam into a uniform swath

Combining swaths to achieve photonic cross-fire

Scenario 1 – ARON-equipped smartphone

ARON
AUGMENTED REALITY OPTICAL NARROWCASTING



Scenario 2 – ARON-equipped automobile

Purpose and goals of ARON Technology Demo Unit

Purpose: Demonstrate that ARON can meet range, data-rate, and miniaturization requirements, while providing an exciting AR immersion experience.

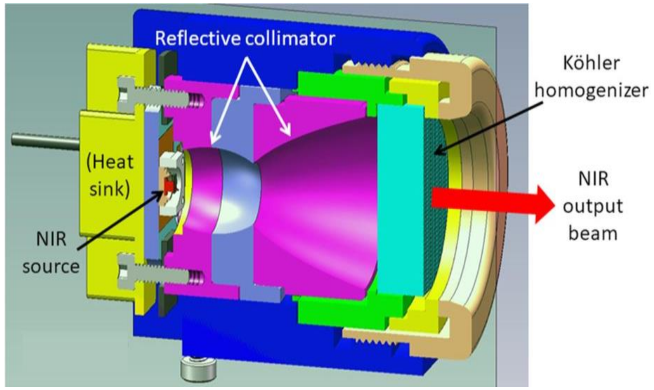
Technical goals:

- Achieve operating range of over 200 meters in broad daylight (eventually increase to 400 meters with ACFPA).
- Demonstrate GUI with beacon information overlaid as AR representation on live video.
- Stream HD video and transfer data files error-free even in presence of moving obstructions.
- Use as test bed for further development.

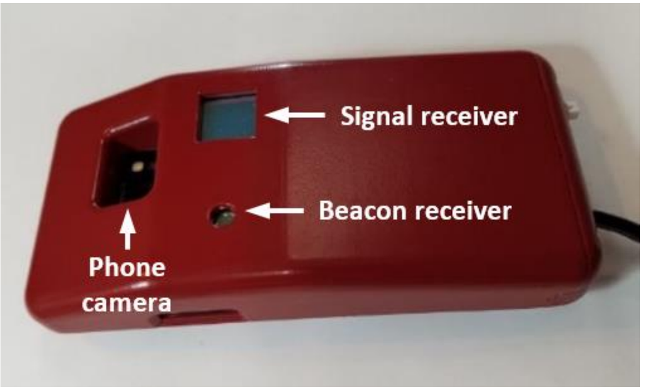
ARON systems can be fully integrated within next-generation smartphones.

ARON Technology Demonstration Unit (TDU)

- Technology demonstration unit (TDU) for ARON has been developed.
- Consists of compact transmitter and receiver mounted in smartphone case.
- Incoming data is merged AR-style with live imagery from phone camera.
- Optical waveband: 810 – 890 nm (NIR).
- Demonstrated Operating range: > 200 m.
- Data rate: >1 Mbps, double what is needed for HD video.



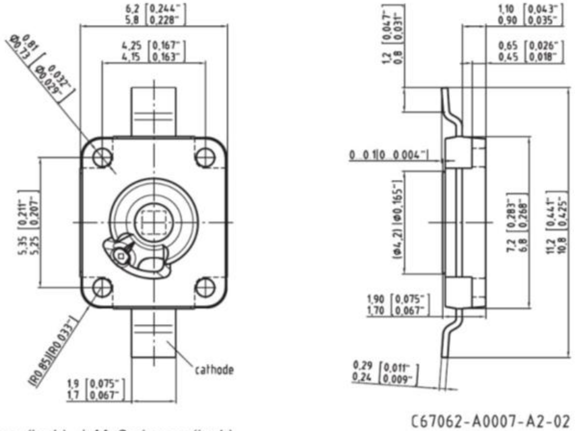
TDU transmitter



TDU receiver

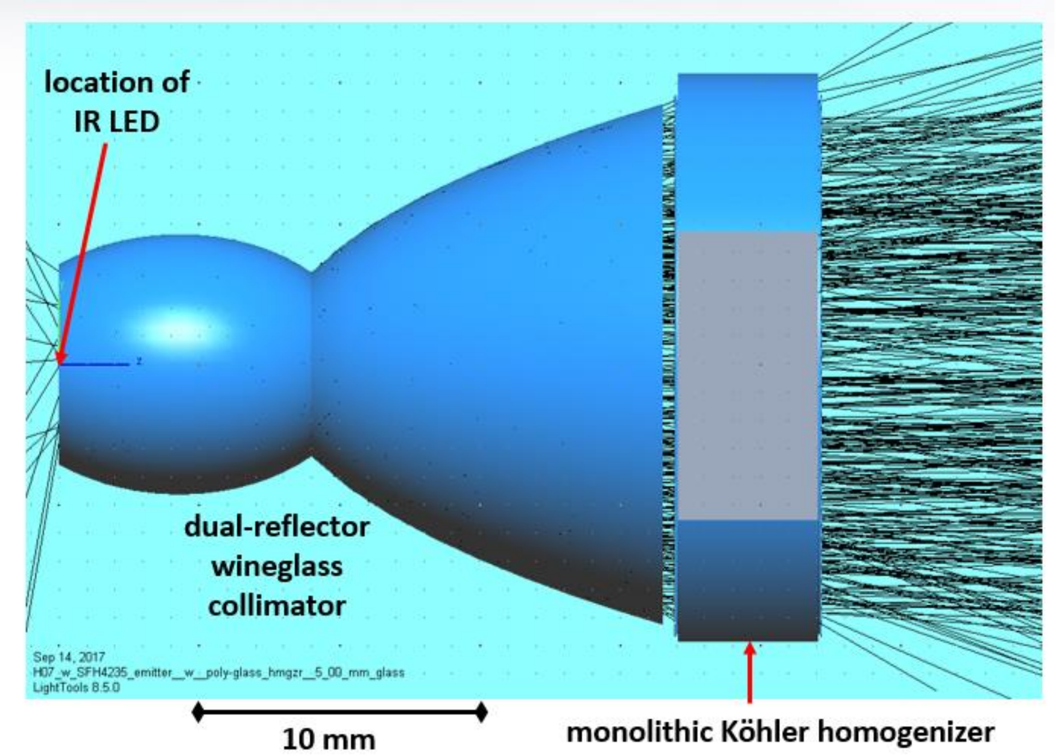
Near IR source used in TDU transmitter

- **OSRAM SFH 4235 high power NIR emitter.**
- **<u>Not</u> a laser source.**
- **<u>Average electrical power</u>: 4 W.**
- **<u>Peak optical output power</u>: 1.4 W.**
- **<u>Optical waveband</u>: 810-890 nm.**
- **<u>Active emitter area</u>: 1-mm-square.**

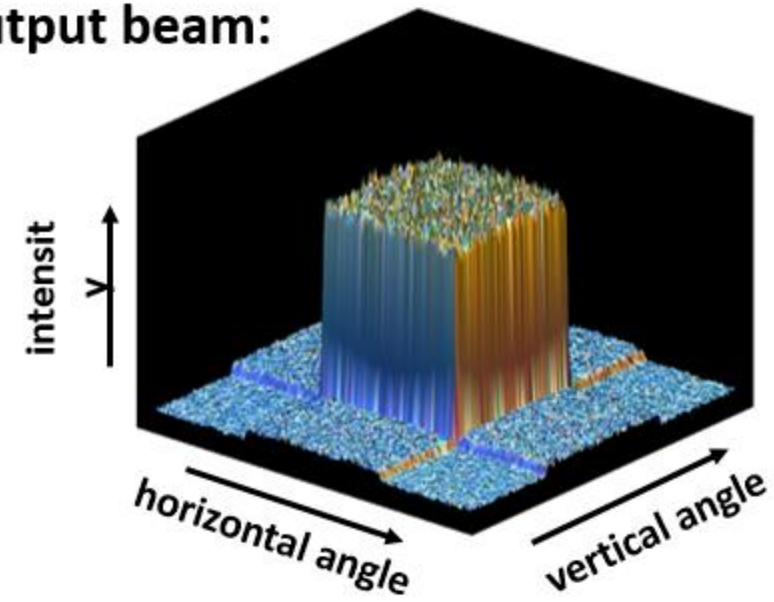


Dimensions in mm (inch). / Maße in mm (inch).
Cathode mark on the bottom side / Kathodenmarkierung auf der Bauteilunterseite

TDU nonimaging transmitter optics



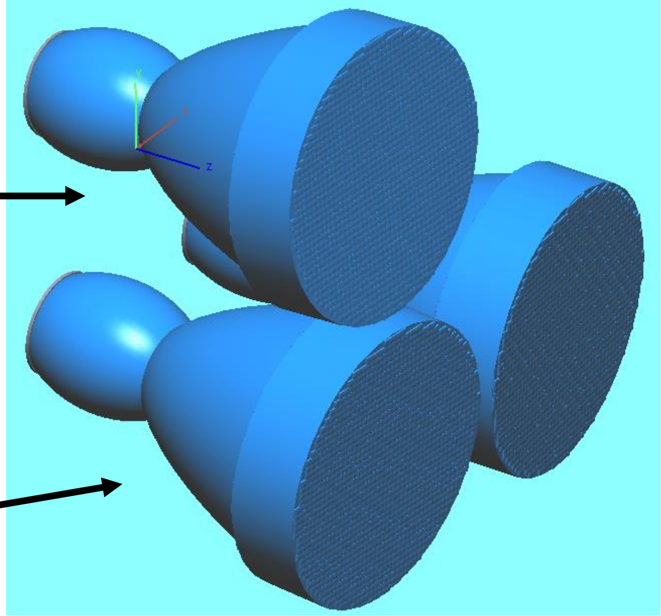
Highly uniform 8°-degree-square output beam:



Surface plot of beam

Beam tiling with multiple TDU transmitters

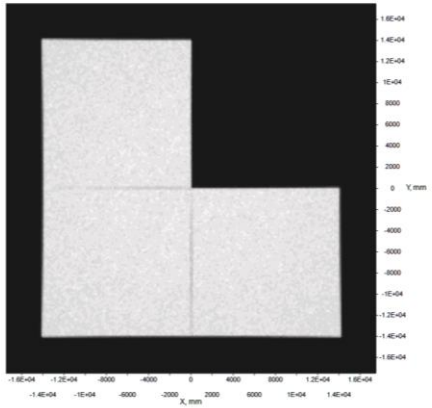
Square beams from multiple transmitters tilted in different directions can produce a tiled beam covering larger angular region. For example, these three transmitters produce L-shaped beam:



Transmitter 1
tilted 4° up
and 4° to left

Transmitter 2
tilted 4° down
and 4° to left

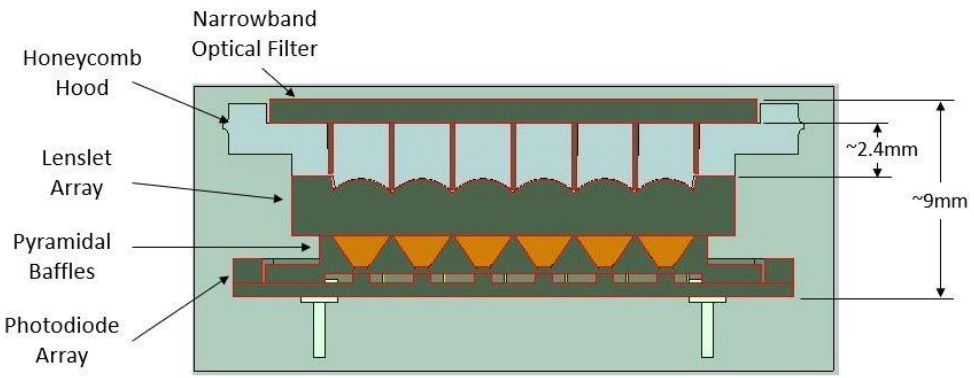
Transmitter 3 tilted
4° down
and 4° to right



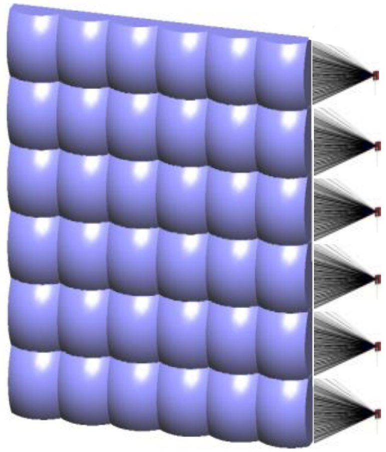
Illumination pattern
100 m from transmitters

TDU nonimaging signal receiver optics

- Optics consists of 6x6 array of lenslets, each with a single detector in its focal plane.
- <u>Aperture of lenslet array</u>: 16.5-mm square.
- <u>Field of view</u>: 3.6° square.



Optics stack

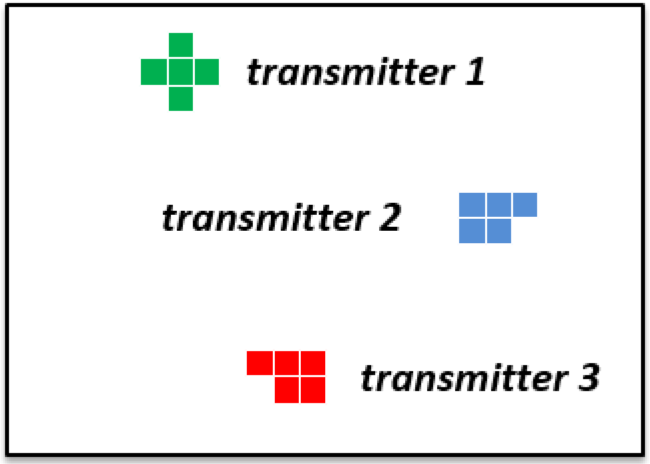


Lenslet array with detector array

Introducing the AI Adaptive Communications Focal-Plane Array (ACFPA)

Novel patented 2D detector array for use in optical communications receivers:

- On-chip circuitry driven by an AI algorithm suppresses output from all detectors, <u>except</u> those receiving bona fide data from transmitters.
- Multi-channel reception.
- Identify identical signals to implement photonic cross-fire.
- Provides advanced location and orientation sensing.
- Large field of view (FOV).
- High data rates.
- High sensitivity.
- Background noise suppression.
- Can be implemented in the form factor of a smartphone camera.

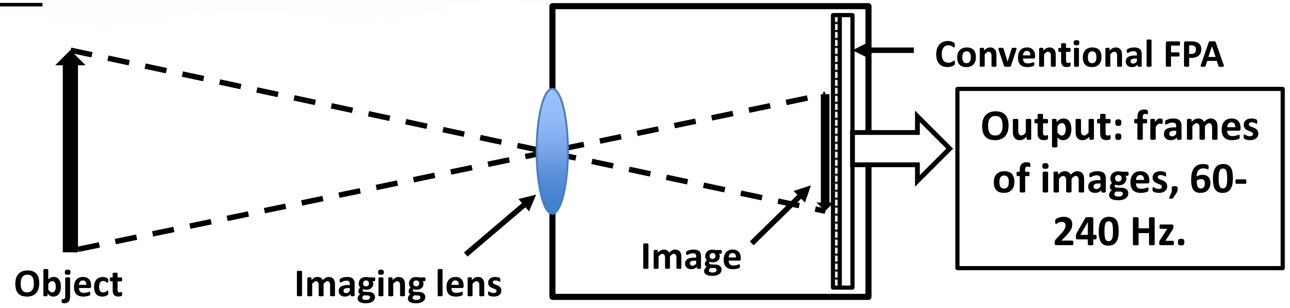


Transmitter signals captured by ACFPA

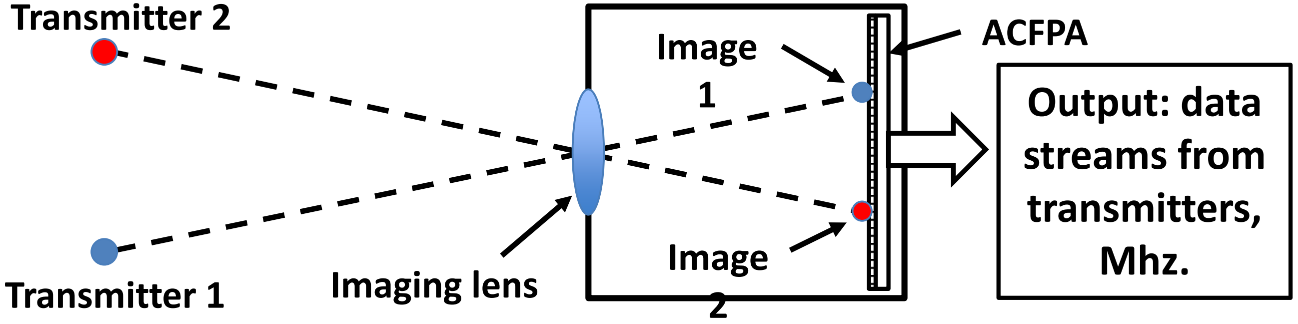
Comparison of ACFPA-based receiver with a conventional video camera

Advanced receiver using patented detector array can simultaneously receive both beacons and signals at high data rates >100 Mbit/s. Beams from ARON transmitters are angularly multiplexed over wide FOV, without having to align receivers with transmitters:

Video camera:

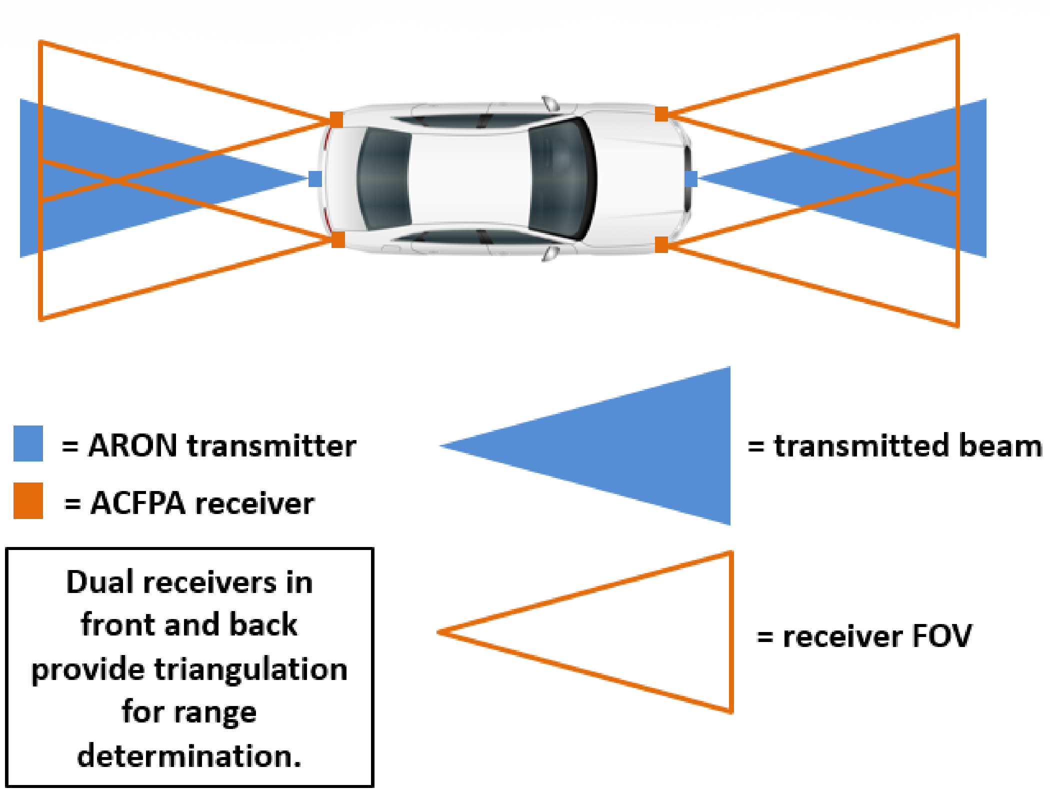


ACFPA-based communications receiver:



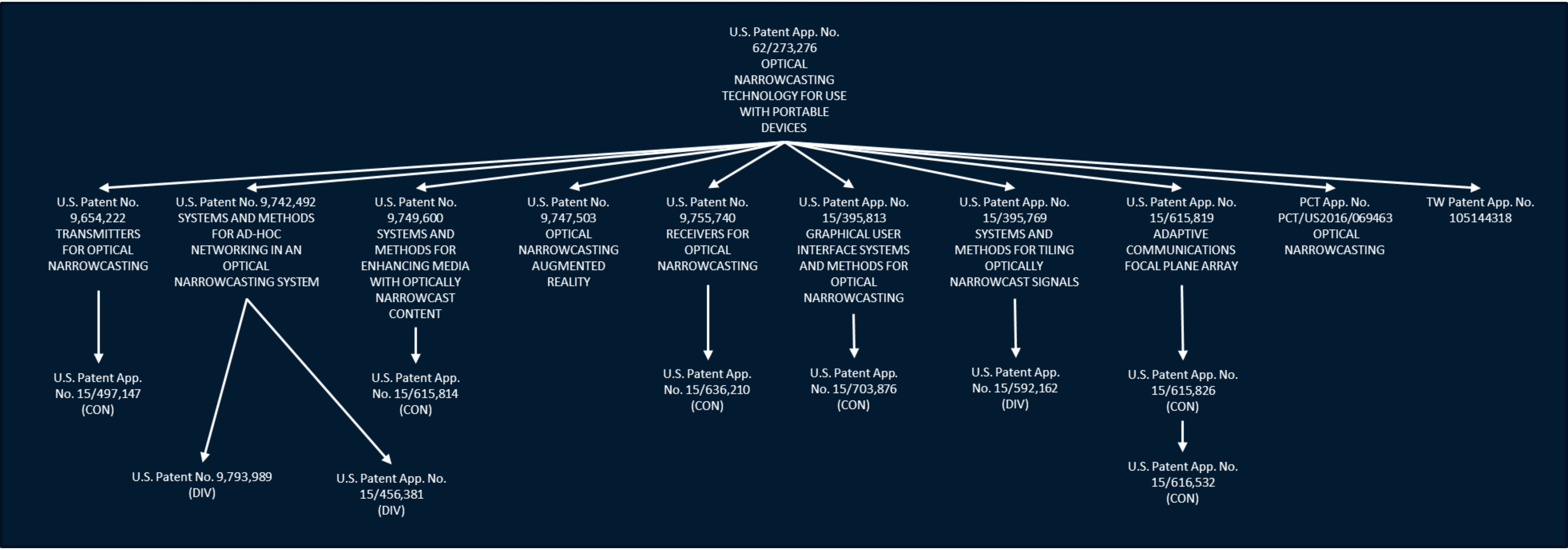
ARON-based vehicular IoT data network

- Localized IoT network for vehicles and nearby fixed structures with practical ranges on the order of 1,000 meters.
- Data transmitted using ARON transmitters, received by ACFPA-based receivers.
- Optimize traffic flow to reduce travel times, accident rates, and fuel usage.
- Localized communications.
- Provides vehicle locations and orientations in 3D.
- Enables Augmented Reality (AR) displays showing locations of nearby vehicles and fixed structures.



ARON patent portfolio tree

21 US patents issued



Summary benefits of ARON

- Alternative communications channel: Does not require Wi-Fi or cellular signal or Internet. Does not require login. A new kind of social networking mode for mobile environments.
- Unregulated and uncensored: No FCC licensing required.
- Many-to-many communications: Information from multiple transmitters can be received simultaneously by multiple users.
- Free to use: No need for data plan, universal use.
- Energy-efficient, low power: Can use batteries or solar power.

  300 X more energy efficient than WiFi.
- Does not need geolocation: Transmitters are located optically.
- Small form factor: Receiver optics will fit in smartphone.
- Li-Fi applications: Patented AI Adaptive Communications Focal-Plane Array may be used in high-data-rate Li-Fi receivers.