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ROBUST SUITE OF TECHNOLOGIES OFFERS SIGNIFICANT ENHANCEMENTS FOR WHISPERING GALLERY MODE (WGM) MICRORESONATOR SENSORS AND LASER SYSTEMS

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WGM microresonators are an immature technology with room for improvement

Microresonators are optical devices that are an important component of microlasers used in optoelectronics, data communications, and sensing. Most microresonators are WGM type, which confine light to a very small volume for signal amplification and extraction and offer high sensitivity in a compact footprint. WGM sensors have been demonstrated in a wide range of sensing applications, including temperature, pressure, acoustic, electromagnetic field, chemical, and biomedical. Products based on WGM microresonators, however, are new to the market, which is growing rapidly due to the wide range of potential applications. Much research is being conducted to improve the performance and practicality of the devices and extend their range of practical applications.

Low cost, compact, ultrasensitive devices for sensing small particles, waves, gases, temperature, humidity, and for data communications

This robust suite of optical devices and methods addresses the weaknesses found with existing WGM devices and offers significant enhancements for numerous sensors and optical communications technology.

Technology Features:

- Provides real-time, label-free, in-situ **detection and sizing of single nanoparticles** using mode-splitting in a monolithic ultra-high-quality (Q>108) optical WGM.
- Includes a system and method to **control loss** within a WGM laser optical system.
- Provides **optical control of the features and performance** of an add-drop filter (ADF) built using the WGM resonator to create an inexpensive method for tuning a laser.
- Provides an **optical isolator** that is the first non-reciprocal transmission device based on parity-time (PT) symmetry that works at useful wavelengths.
- Offers portable, miniature sensors for air-quality measurements with **simultaneous sensing** for air quality, gas detection, temperature, pressure, and humidity.
- Includes **cell phone–based monitoring** for portable sensors as well as imaging of resonator mode patterns using a cell-phone camera.
- A chip-sized integrated circuit enables **new microwave or millimeter wave electronic devices** with high isolation, wide bandwidth, and low insertion loss.
- Enables a **compact, ultra-sensitive sensor probe** with a coupling system that supports high-efficiency coupling of light into and out of the resonant microsphere tip.

- Includes a **broad-bandwidth acoustic sensor** with simultaneous sensitivity that is three orders of magnitude higher than piezoelectric.
- Offers a compact, **barcode-based sensing system** that uses collective multimode information to measure the temperature directly from the WGM spectrum.

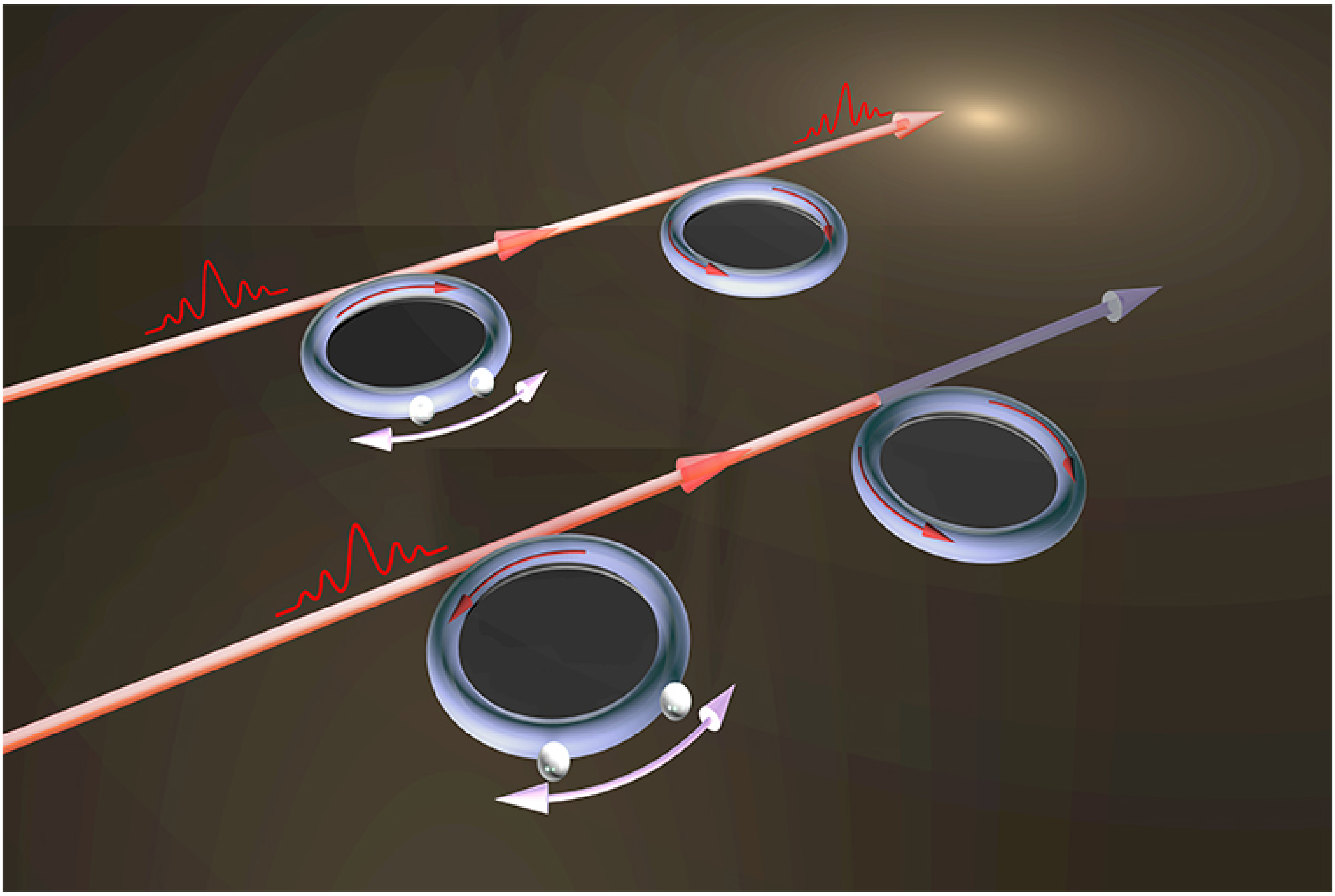
Solution Advantages

- **Amplifies weak signals:** Improves signal-to-noise ratio to strengthen weak signals in optical systems.
- **Improves emission:** Offers better control (directionality and tuning) of light and laser emission in on-chip micro- and nanostructures.
- **Enhanced particle detection system:** Provides a simple, inexpensive, accurate, highly sensitive (threshold of 10 nm), and portable system.
- **Increases laser efficiency and lowers power:** Lowers the power level needed to reach lasing threshold and increases energy efficiency by up to 4x.
- **Improves noise suppression:** Offers real-time, in-situ, sensitive detection (threshold of 10nm) with superior noise suppression.
- **Reduces device and sample size:** Enables a smaller device (by orders of magnitude), while simultaneously reducing the needed sample size.
- **Eliminates labelling:** Does not require labeling of nanoparticles.
- **Reduces laser tuning costs:** Active WGM resonator improves add/drop filter multiplex to enable a WGM system with much narrower channels to reduce costs related to laser tuning.
- **Eliminates Faraday effects:** Provides an alternative to existing Faraday rotator-based optical isolators.
- **Smaller semiconductor optical amplifiers:** Non-reciprocal transmission device based on PT symmetry provides a multifunctional option (e.g., lasing, ADF, isolation) that is 100x smaller than semiconductor optical amplifiers.
- **Enables in-situ testing:** Small on-chip sensor enables in situ testing.
- **Improves nanoscale sensing:** Hypersensitive, easy-to-fabricate system offers efficient in/out coupling and can detect multiple parameters simultaneously.
- **Compatible:** Systems are integrated circuit based and can be connected to and controlled using consumer devices such as cell phones and laptops and can interface with device camera.
- **Enhances acoustic sensor sensitivity:** Offers both high sensitivity that is 3 orders of magnitude higher than piezoelectric and unprecedented broad bandwidth in an acoustic sensor.
- **Cost effective:** Compact design offers low-cost wafer production.
- **Improves tracking:** Overcomes the limitation of conventional thermal sensing based on single-mode tracking.

Potential Applications

- Sensing electromagnetic waves (i.e., infrared, ultraviolet, acoustic, gravitational), very small particles, temperature, pressure, humidity, chemicals, etc. in applications such as
    - Environmental monitoring in gases and liquids
    - Biomedical/biological
    - Biodefense
    - Energy harvesting
    - Sonar
    - Non-destructive evaluation of materials

    - Thermal imaging
    - Barcode-like tracking
- Laser systems
- Optical communications (e.g., add/drop filters, multiplexers, modulators, optical switches, and optical isolators)
- Secure transfer of quantum information
- Optical computing



Electromagnetically induced transparency (EIT) is "tuned" by two particles on the optical resonator. The different locations of particles control the propagation of light in either clockwise or counterclockwise directions, which switch on (upper configuration) or off (lower configuration) the interference of light, leading to controllable brightness (EIT) and darkness in the output. Image credit: Yang Lab