Optoplex's 90deg Optical Hybrids and Integrated Receivers

for

Quantum Random Noise Generators (QRNG)

Quantum Random Number Generators (QRNGs) play a crucial role in enhancing the security of quantum communication systems. Here's how:

- Key Generation in Quantum Key Distribution (QKD):
  - QKD protocols like BB84 rely on random bit sequences to encode and decode information.
  - QRNGs provide the truly random bits needed for key generation.
  - These random bits are used to create shared secret keys between communicating parties, forming the foundation of secure communication.
- Device Independence:
  - In some QKD implementations, QRNGs can contribute to device-independent security.
  - By ensuring the randomness of measurement settings, QRNGs help minimize the impact of potential flaws or loopholes in the quantum devices themselves.
- Encryption and Decryption:
  - Strong encryption algorithms require high-quality random numbers.
  - QRNGs provide the necessary randomness for key generation and other cryptographic operations in quantum communication systems.
- Improving Security Against Attacks:
  - Traditional random number generators can be susceptible to various attacks.
  - QRNGs, based on the fundamental unpredictability of quantum phenomena, offer enhanced security against eavesdropping and other attacks.

In essence, QRNGs provide the bedrock of randomness essential for the security and reliability of quantum communication protocols. They ensure that the keys used for encryption and decryption are truly unpredictable, making it extremely difficult for adversaries to intercept or decode the transmitted information.

Key Advantages of Using QRNGs in Quantum Communication:

- Unpredictability: Quantum phenomena are inherently random, making it impossible to predict the output of a QRNG.
- Security: QRNGs provide a high level of security against various attacks, including those targeting traditional random number generators.
- Trust: The use of QRNGs can increase trust in the security of quantum communication systems.

By leveraging the power of quantum mechanics, QRNGs contribute significantly to the advancement of secure and reliable quantum communication technologies.

Sources and related content

Optoplex's 90deg Optical Hybrid and Integrated Receivers for QRNG

Optoplex's proprietary 90deg optical hybrids and dual-polarization 90deg hybrids (aka 2x8 DP-QPSK coherent mixer) are based on free-space athermal optical design.

Key Features and Benefits

- Purely passive (no need for external electric power)
- Compact size
- Based on free-space bulk-optics design
- Polarization diversified version also available

Applications

- QPSK and BPSK optical demodulations in optical communications
- Coherent doppler lidars
- Coherent detection in a DAS sensing
- Coherent detection in biomedical imaging, e.g., OCT
- Quantum communications systems
  - High CMRR coherent receivers
  - Quantum Random Noise Generators (QRNG)
- Quantum Sensors

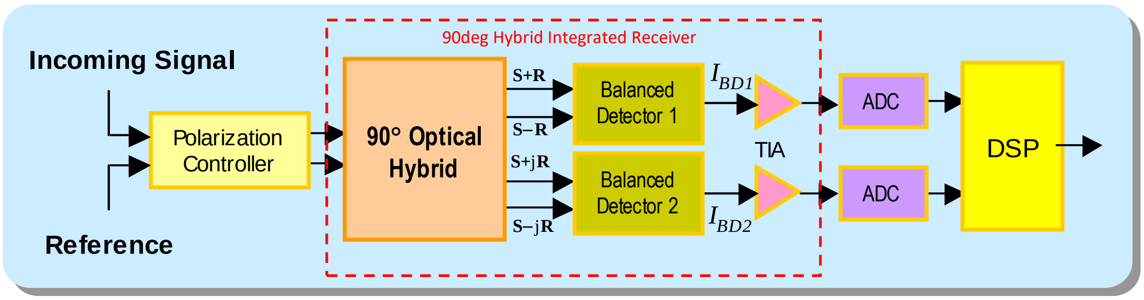

Figure 1, 90deg optical hybrid in coherent detection

QRNGs based on Vacuum Fluctuations

One prominent type of optical QRNG relies on measuring the vacuum fluctuations of the electromagnetic field. These fluctuations are inherently random due to the Heisenberg uncertainty principle.

- **Coherent Detection:** To measure these tiny fluctuations, coherent detection is often employed. This is where 90° optical hybrids and coherent receivers come into play.
- **How it works:**
  1. **Vacuum Input:** One input of the 90° optical hybrid is left open, effectively inputting vacuum fluctuations.
  2. **Local Oscillator (LO):** A strong coherent light source (the LO) is input into the other port of the hybrid.
  3. **Interference:** The vacuum fluctuations and the LO interfere within the hybrid.
  4. **Quadrature Measurement:** The outputs of the hybrid are sent to balanced photodetectors. Due to the 90° phase shifts introduced by the hybrid, the detectors measure different quadratures (amplitude and phase) of the vacuum fluctuations.
  5. **Random Numbers:** The measured fluctuations are then digitized and processed to generate random numbers.

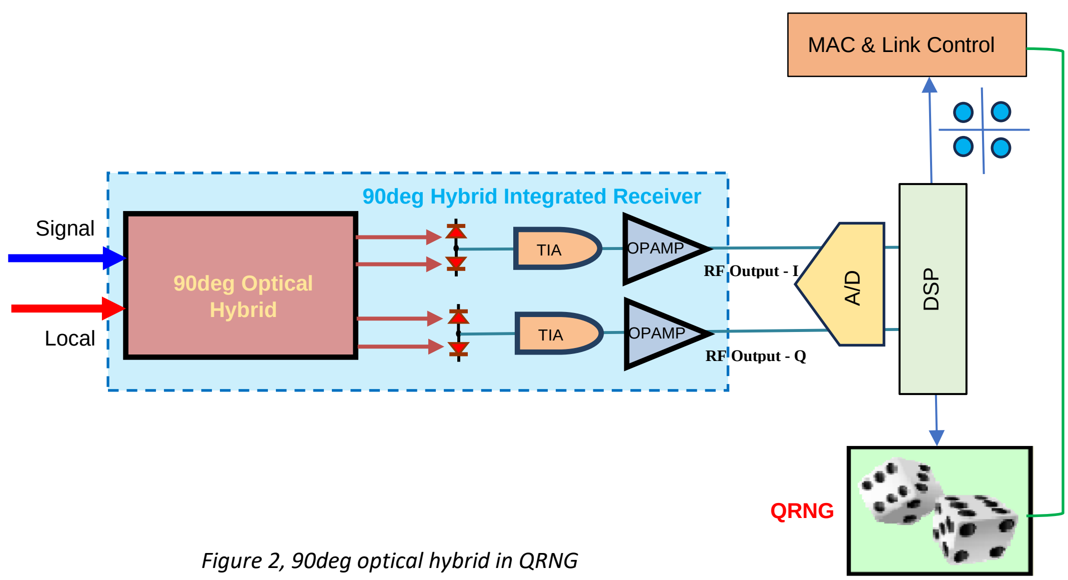

Figure 2, 90deg optical hybrid in QRNG

Polarization-diversified 90deg optical hybris (aka dual-polarization 90deg hybrid, or 2x8 DP-QPSK coherent mixer) is also available. It is also widely used in QRNG

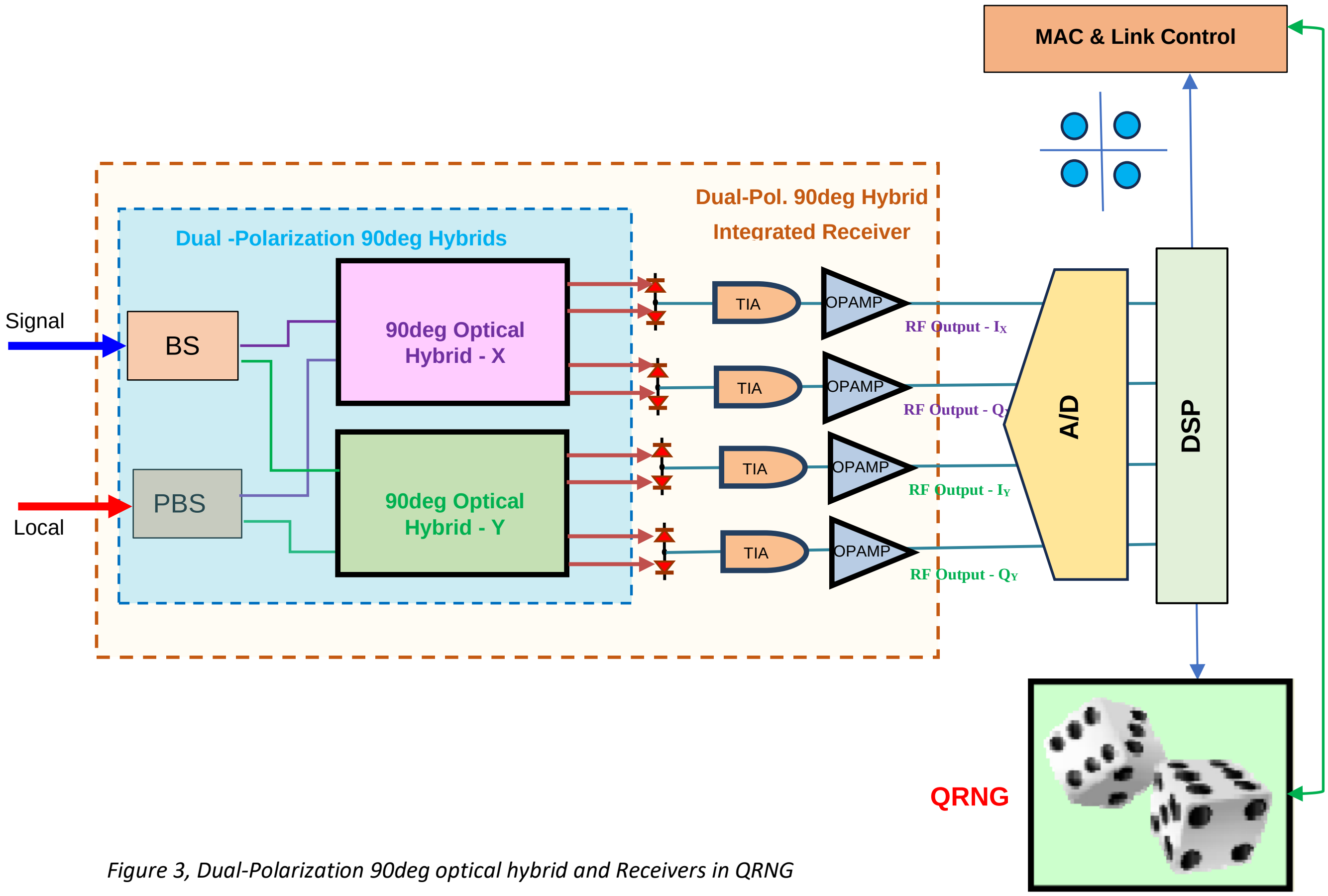

Figure 3, Dual-Polarization 90deg optical hybrid and Receivers in QRNG

Why 90° Optical Hybrids are Crucial:

- **Efficient Measurement:** The 90° hybrid allows for the efficient measurement of both quadratures of the vacuum fluctuations, maximizing the information extracted.
- **Balanced Detection:** The outputs of the hybrid are designed to be balanced, which helps to suppress common-mode noise and improve the signal-to-noise ratio.

90° optical hybrids and coherent receivers are essential components in optical QRNGs that rely on measuring vacuum fluctuations. They enable efficient and precise measurement of these quantum fluctuations, which are then used to generate truly random numbers. Their role in other optical QRNG schemes might vary, but their ability to perform coherent detection makes them a valuable tool in this field.

In addition to 90deg optical hybrids and 2x8 DP-QPSK coherent mixers, Optoplex also manufactures the integrated coherent receivers of the 90deg optical hybrid with balanced receivers. The bandwidths of the balanced receivers are 100, 200, 400, 1200 and 1600MHz.

Please find out the details on the product brochure.

Implementation Examples

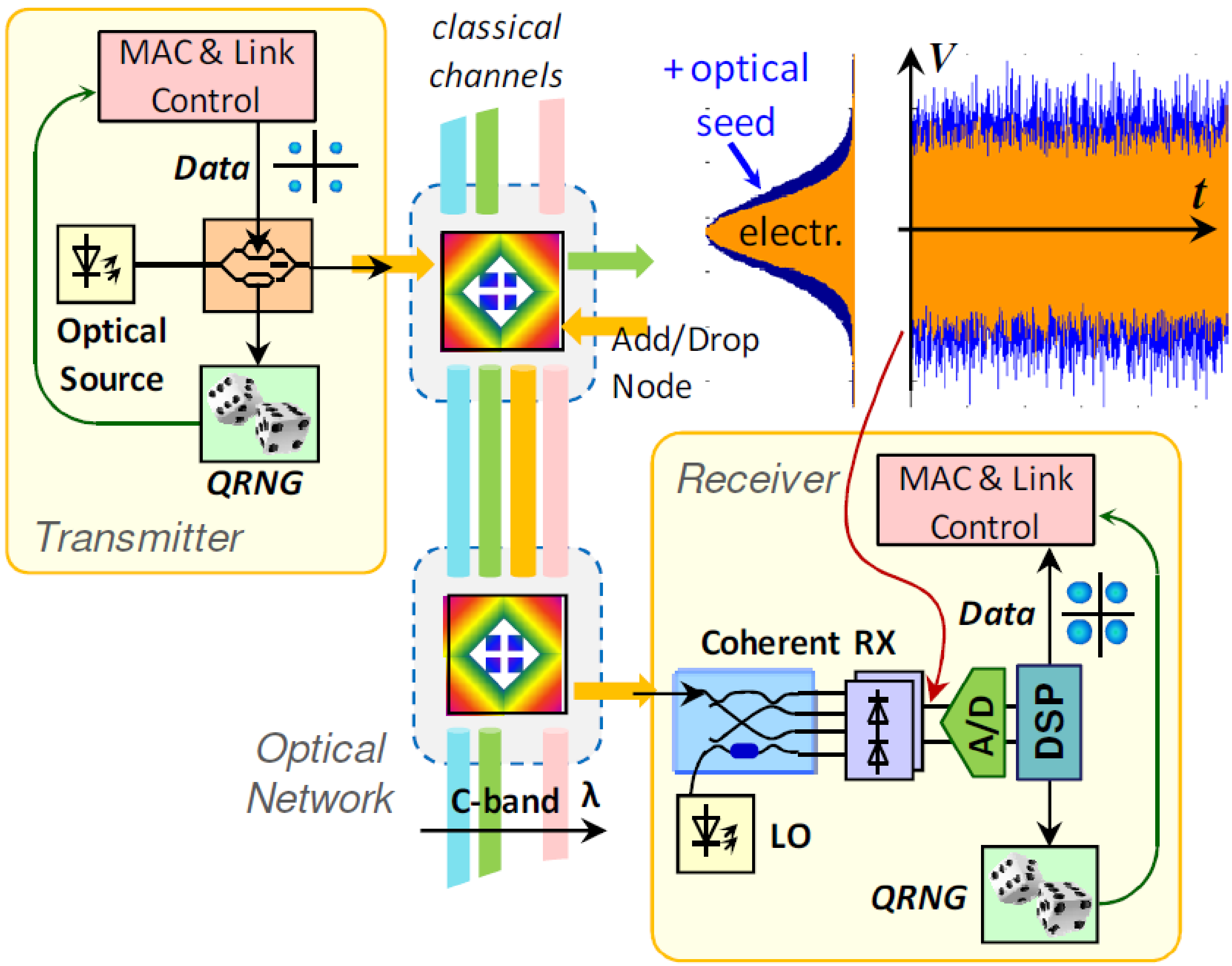

Figure 4, Current communication link with integrated randomness engines using a 90deg optical hybrid with integrated balanced receivers *(Courtesy of Dinka Milovančev etc. Quantum Physics, arXiv:2007.10210v1. [IEEE Journal of Selected Topics in Quantum Electronics](), Volume: 26, [Issue: 5](), Sept.-Oct. 2020)*

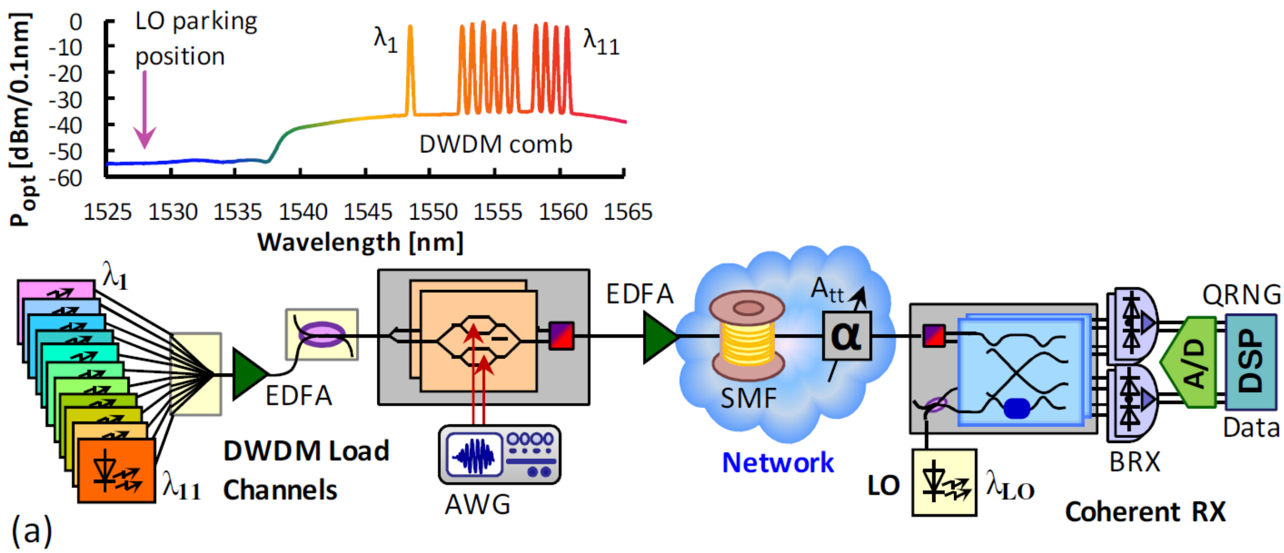

Figure 5,Using a polarization-diversified 90deg optical hybrid (aka 2x8 DP-QPSK coherent mixer) with integrated balanced receivers in the receiving side for QRANG *(Courtesy of Dinka Milovančev etc. Quantum Physics, arXiv:2007.10210v1. IEEE Journal of Selected Topics in Quantum Electronics, Volume: 26, Issue: 5, Sept.-Oct. 2020)*

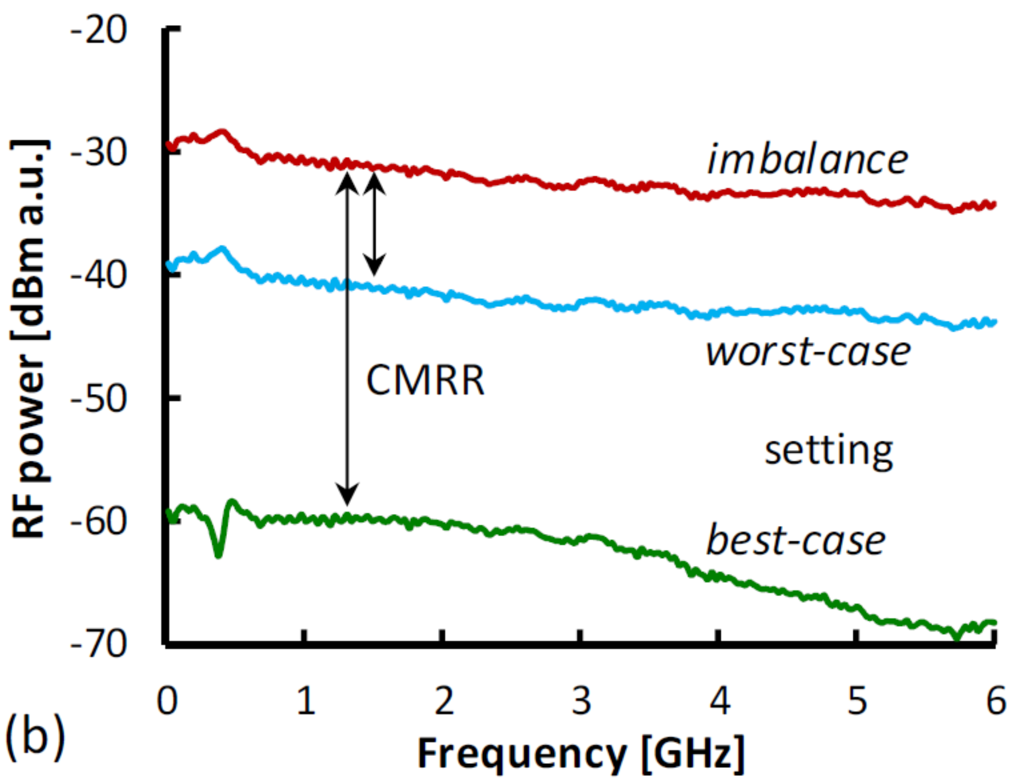

Figure 6, Measured noises in a QRNG *(Courtesy of Dinka Milovančev etc. Quantum Physics, arXiv:2007.10210v1. IEEE Journal of Selected Topics in Quantum Electronics, Volume: 26, Issue: 5, Sept.-Oct. 2020)*