Call 2021
Final Evaluation

QUANTERA
DECADE OF IMPACT 2016-2026

DISCO

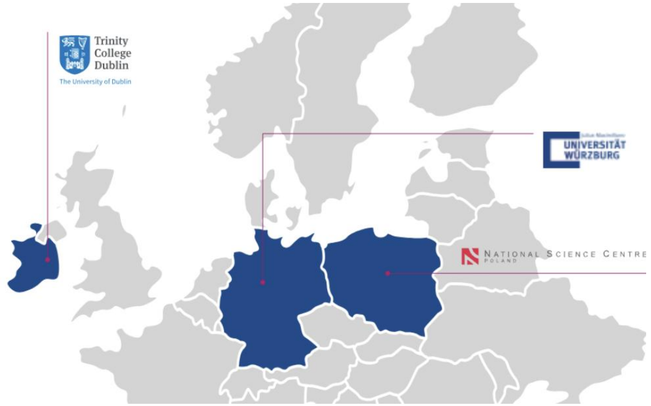
Dicke-enhanced single-emitter strong coupling at ambient conditions as a quantum resource

Ortwin Hess
Trinity College Dublin, on behalf of the DISCO consortium

QuantERA Strategic Conference, Basel
28 September 2026

COLLABORATION AND PROJECT OVERVIEW

Aim: exploit Dicke-enhanced coupling within a single emitter for quantum control at ambient conditions



Trinity College Dublin, Ireland

Ortwin Hess (coordinator)
Quantum theory and computational modelling

University of Würzburg, Germany

Bert Hecht
Nanofabrication and optical experiments

Wrocław University of Science and Technology, Poland

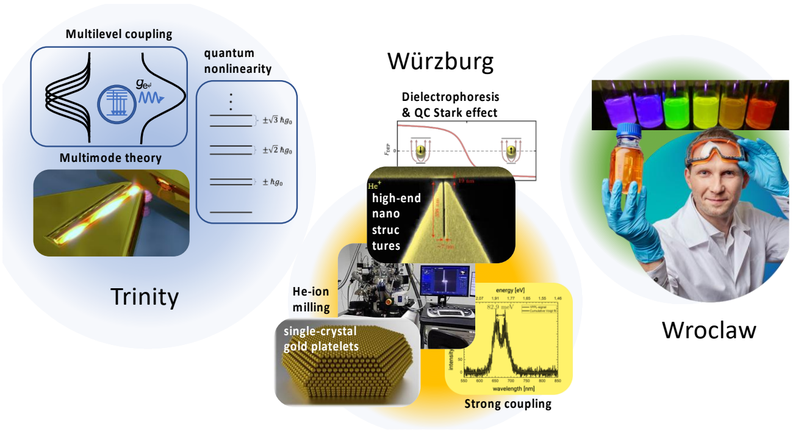
Artur Podhorodecki
Quantum-dot materials and synthesis

Joint cavity redesign, shared modelling and experimental feedback, and a doctoral research exchange

July 2022 –June 2026 including a 12-month no-cost extension

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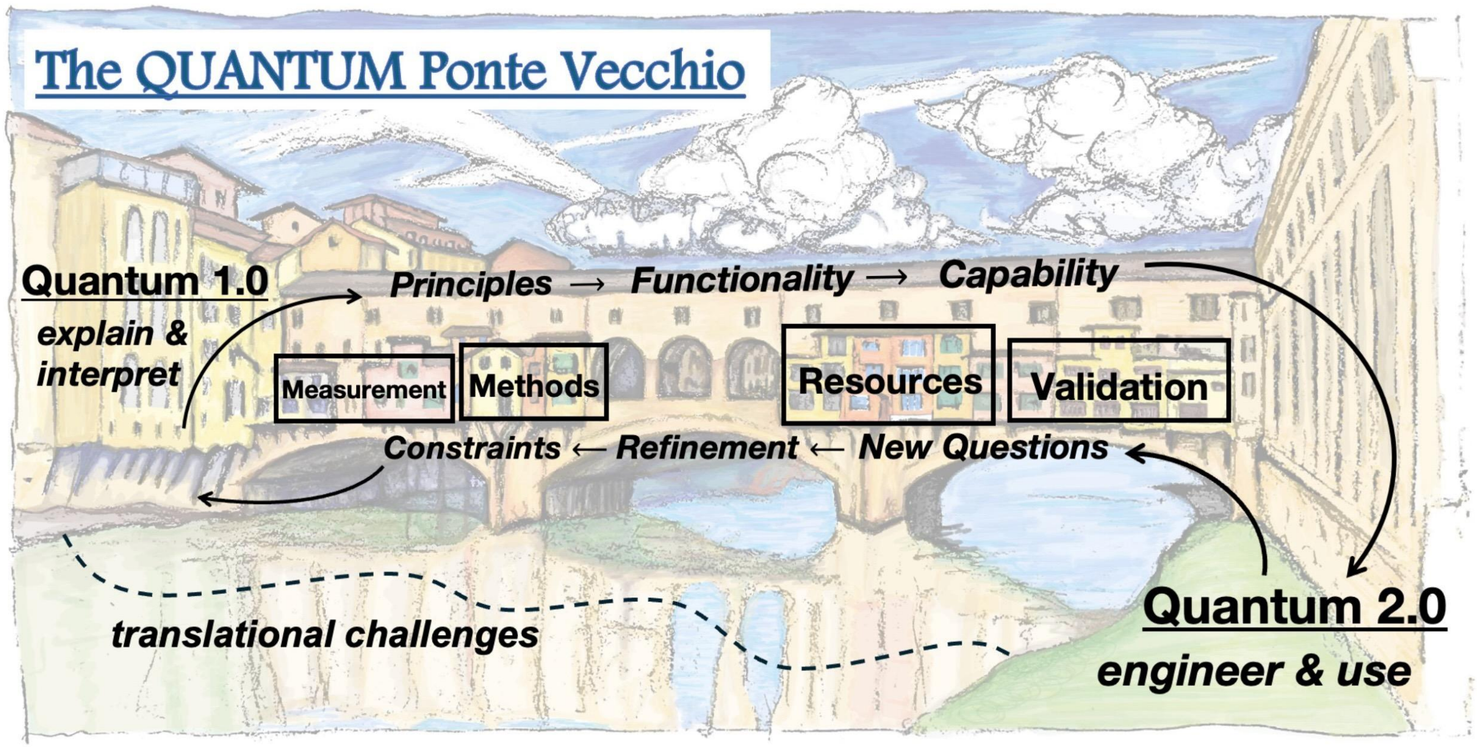
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MOTIVATION: THE QUANTUM PONTE VECCHIO



O. Hess, APL Quantum 3, 020401 (2026). Artwork: Rita Marie Hess

Quantum Bridging

Turning quantum principles into useful functionality

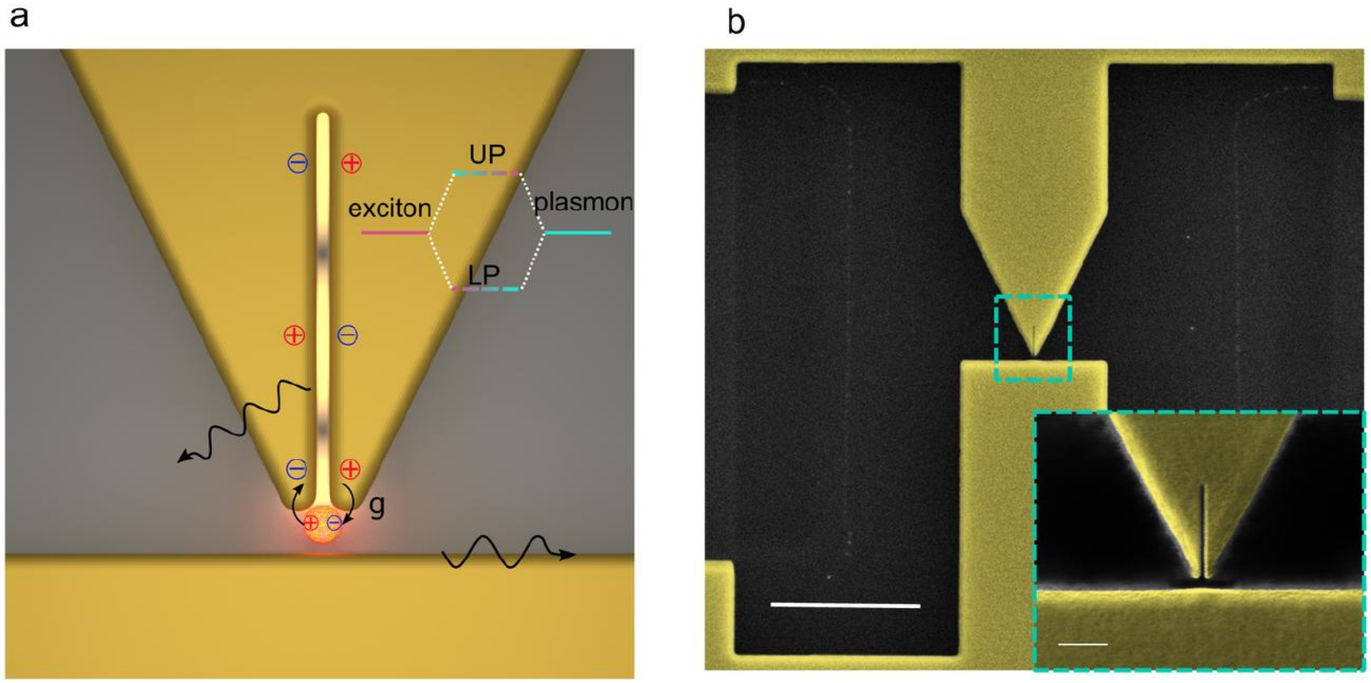
DISCO contributes

Theory for lossy nanocavities

Control concepts

Room-temperature building blocks

SUCCESS STORY: AN ON-CHIP STRONG-COUPLING PLATFORM



Schematic and electron micrograph. Main scale bar: 1 μm, inset: 100 nm

Qin et al., Nano Letters (2026), Fig. 1a–b. DOI: 10.1021/acs.nanolett.5c05910

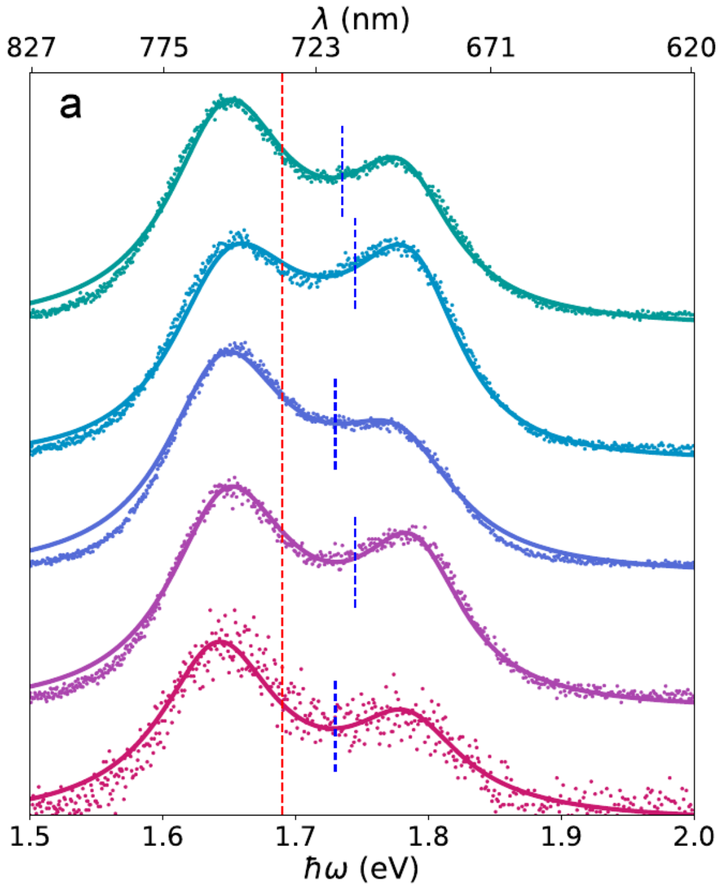
EXPERIMENT

An electrically addressable plasmonic slit cavity

Position colloidal quantum dots at the optical hot spot

Measure emission at room temperature

ROOM-TEMPERATURE STRONG COUPLING



g ≈ 72–123 meV

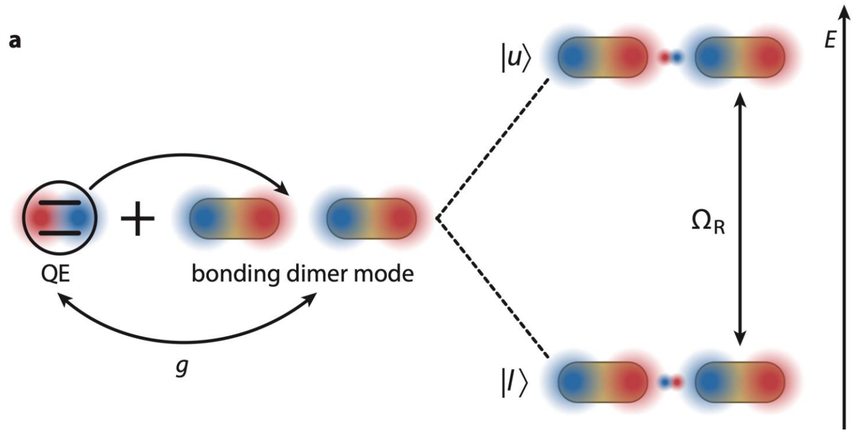
Fitted coupling strengths across three devices

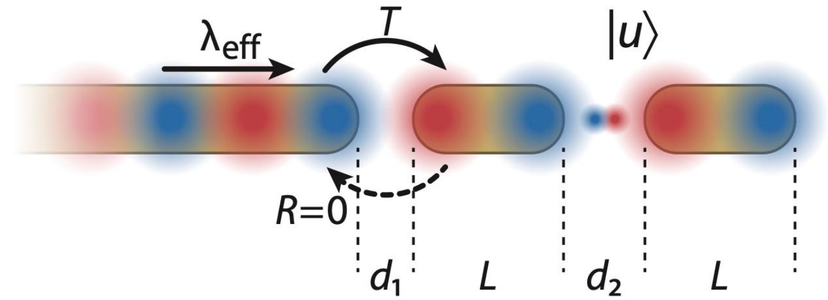
Split photoluminescence spectra
resolve the hybrid light–matter response

Next test: establish photon statistics
of the coupled device

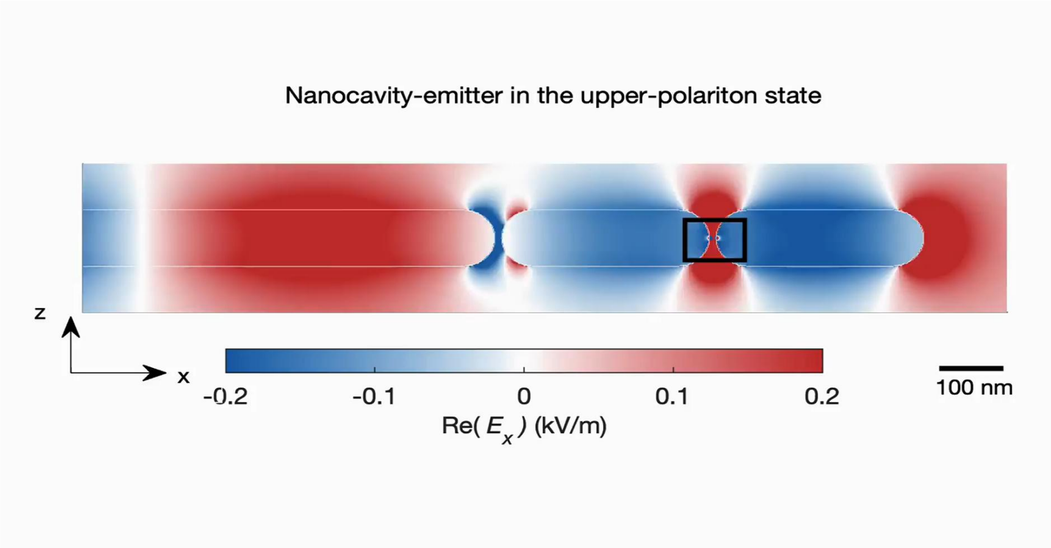
Qin et al., Nano Letters (2026), Fig. 4a and discussion. Dots: measurements. Lines: fits

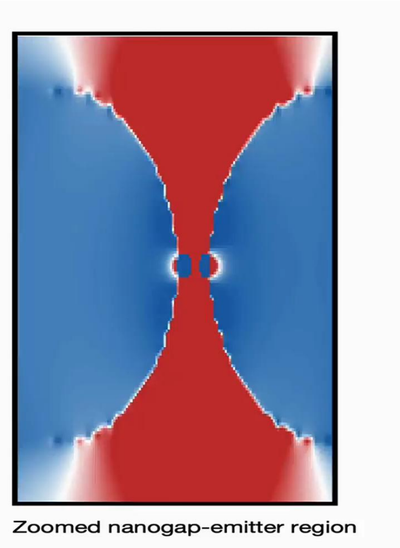
SCIENTIFIC ADVANCES:
SEMI-CLASSICAL THEORY FOR LOSS AND CONTROL





Y Lai, ... B Hecht and O Hess, *Nature Communications* (2024)
Z Jalali-Mola ... and O Hess, *APL Quantum* (2024)



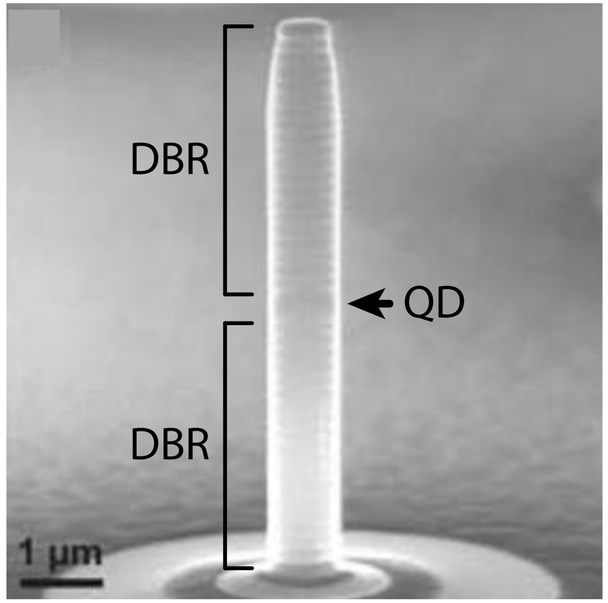

Zoomed nanogap-emitter region

Selective polariton preparation

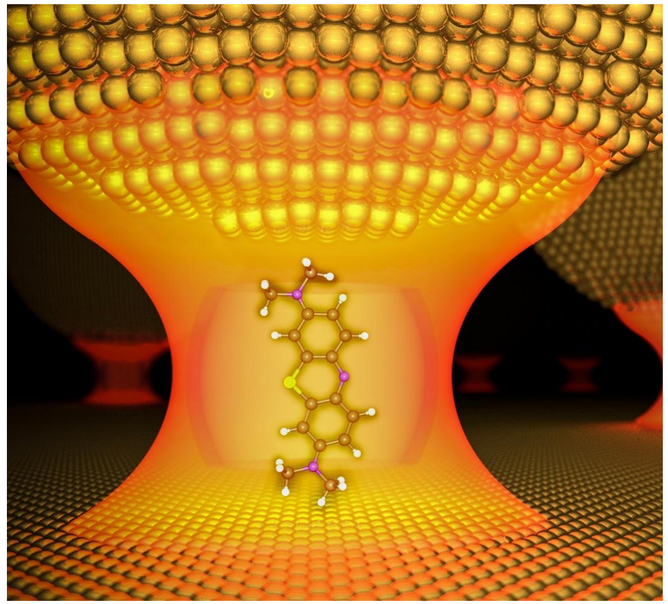
Coherent perfect absorption provides a theoretical route to select hybrid light–matter states

Collective slow-wave emitter dynamics suggest further routes toward quantum memory

SCIENTIFIC ADVANCES: QUANTUM THEORY FOR LOSS AND CONTROL



Nature **432**, 197 (2004)



Nature **535**, 127 (2016)

Quantum theory of dispersive open nanocavities

A quantum quasinormal-mode framework treats radiative leakage and dispersive material absorption

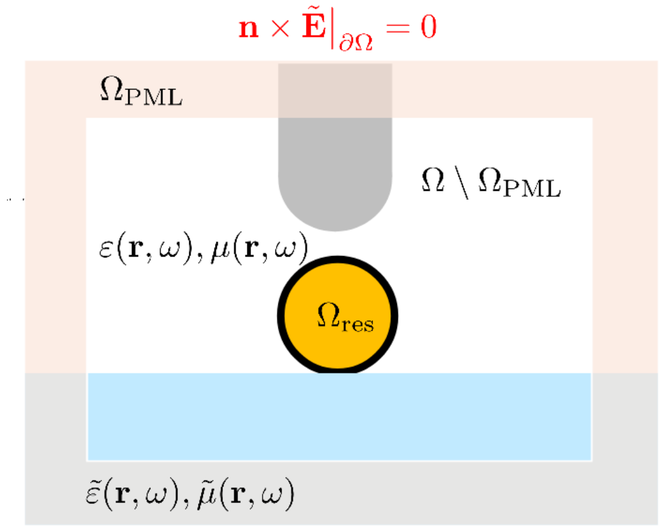
[L Meschede, D Clarke and O Hess, *APL Quantum* **3**, 016103 (2026)]

QUANTUM MODES FOR OPEN, LOSSY NANOCAVITIES

Radiative leakage, absorption and quantum noise in one framework

Regularised electromagnetic modes

Perfectly matched layers (PMLs) regularise the outgoing fields.



Canonical quantum modes

Macroscopic QED gives bosonic mode operators and consistent quantum noise.

$$\hat{\mathbf{E}}^{(+)}(\mathbf{r}) = \sum_n \tilde{\mathbf{E}}_n^{\mathrm{sym}}(\mathbf{r})\hat{a}_n$$

Spatial mode profiles define the field.
Quantum operators describe its excitations.

Benchmarked against macroscopic QED

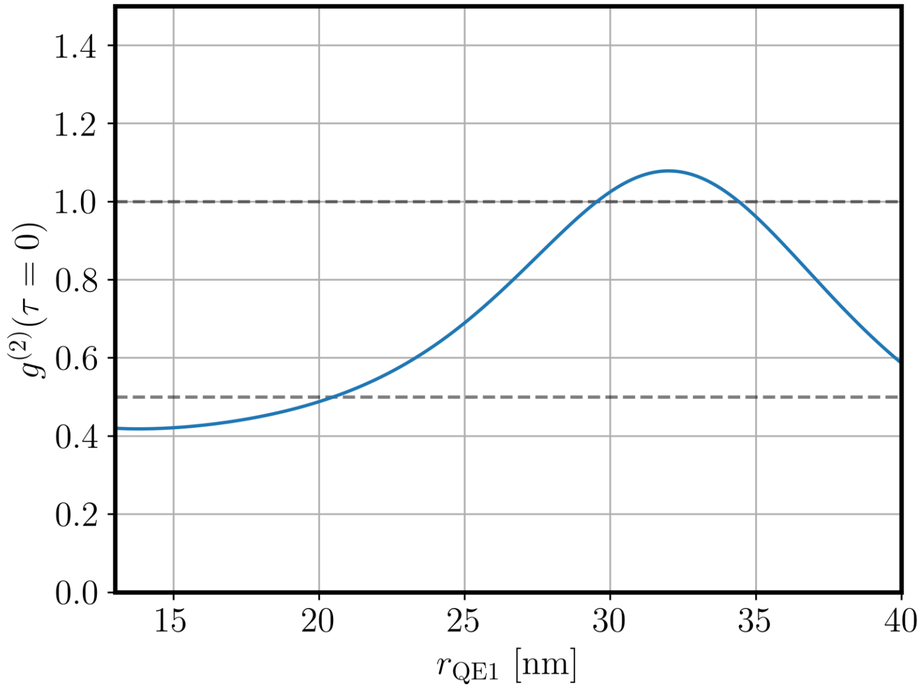
Decay dynamics, emitted fields and Purcell spectra

L. Meschede, D. D. A. Clarke & O. Hess, APL Quantum 3, 016103 (2026). DOI: 10.1063/5.0292776

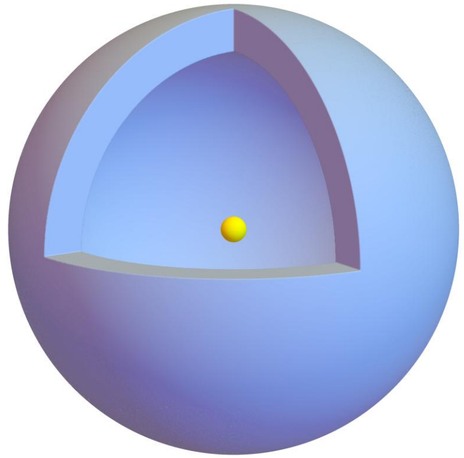
PHOTON STATISTICS IN A HYBRID NANOCAVITY

Illustrative calculation: incoherently pumped quantum emitter

Photon correlations at a fixed radius r = 626 nm



Au nanoparticle in a hollow Si cavity



Full multimode field correlations determine the photon statistics.

$g^2(0) < 1$: nonclassical, sub-Poissonian statistics

Formalism: APL Quantum 3, 016103 (2026).

DELIVERY AT PROJECT CLOSURE

Established

Quantum theory for dissipative nano-optics

Deterministic spatial positioning of quantum dots

Room-temperature strong coupling

New theoretical routes to state control

Still to demonstrate

Single-emitter Dicke enhancement

Stark-controlled avoided crossing

Complete single-photon transistor

Key limits: quantum-dot stability and spectral diffusion up to about 50 meV

SCIENTIFIC OUTPUTS AND RESPONSIBLE RESEARCH

4 **associated research publications**
Nature Communications, APL Quantum and Nano Letters

Open research

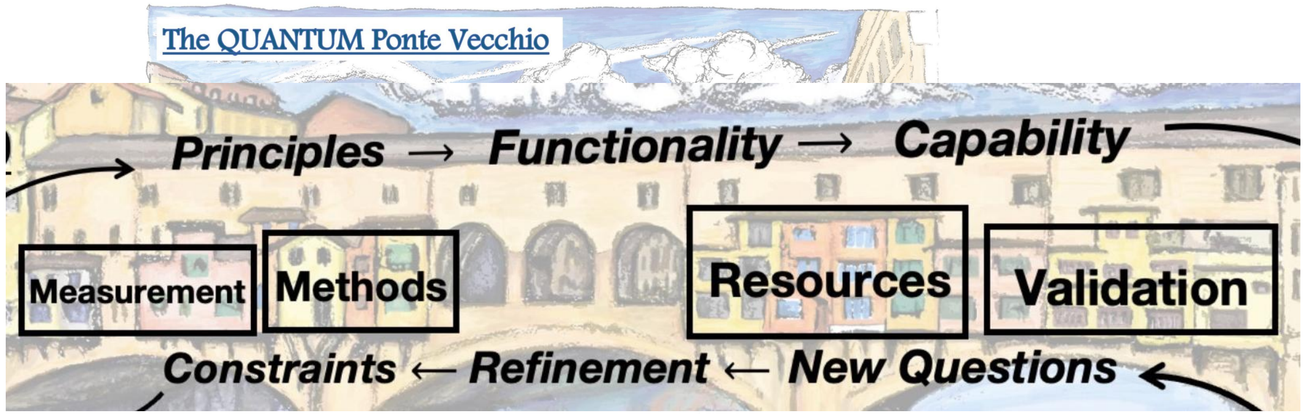
Open-access papers and a Zenodo dataset for the coherent-perfect-absorption study

Training and exchange

Doctoral work and a Würzburg exchange, postgraduate teaching, META workshop and Women in STEMM outreach

IMPACT AND CONTINUATION THROUGH RINN QUANTUM

Work on the Bridge



Integrated quantum-photonics developers and researchers in sensing and communication

Long-term opportunities include controlled emission, quantum-state preparation and nanoscale memories

Further validation and engineering are needed before these become operational technologies

rinn Quantum

Co-Directors:
John Goold and Ortwin Hess

€40m base funding + €22m industry contrib.
8 years, 8 institutions, 16 PI, 72 PhD, 109 postdoc years

DISCO helped support the successful application for Rinn Quantum

One of several contributing foundations for Ireland's new national centre for quantum research

IMPACT AND CONTINUATION THROUGH RINN QUANTUM

Potential users

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WHAT’S NEXT

DISCO established theory and a platform for room-temperature quantum photonics

Stabilise emitters and resolve coupled-device photon statistics

Demonstrate experimentally controlled quantum functionality

Continue the consortium’s work through Rinn Quantum and European collaborations

Thank you

Co-funded by
the European Union