Travelling Wave Photon Energy Lifters (TWPELs) for QUART&T

Felix Ahrens - TIFPA/FBK

QUART&T Kick-off 21/02/2025

Istituto Nazionale di Fisica Nucleare
TIFPA
Trento Institute for Fundamental Physics and Applications

QUART&T
QUANTUM ARCHITECTURES FOR THEORY & TECHNOLOGY

FBK
SENSORS AND DEVICES
FONDAZIONE BRUNO KESSLER

Travelling Wave Photon Energy Lifters (TWPELs) for QUART&T

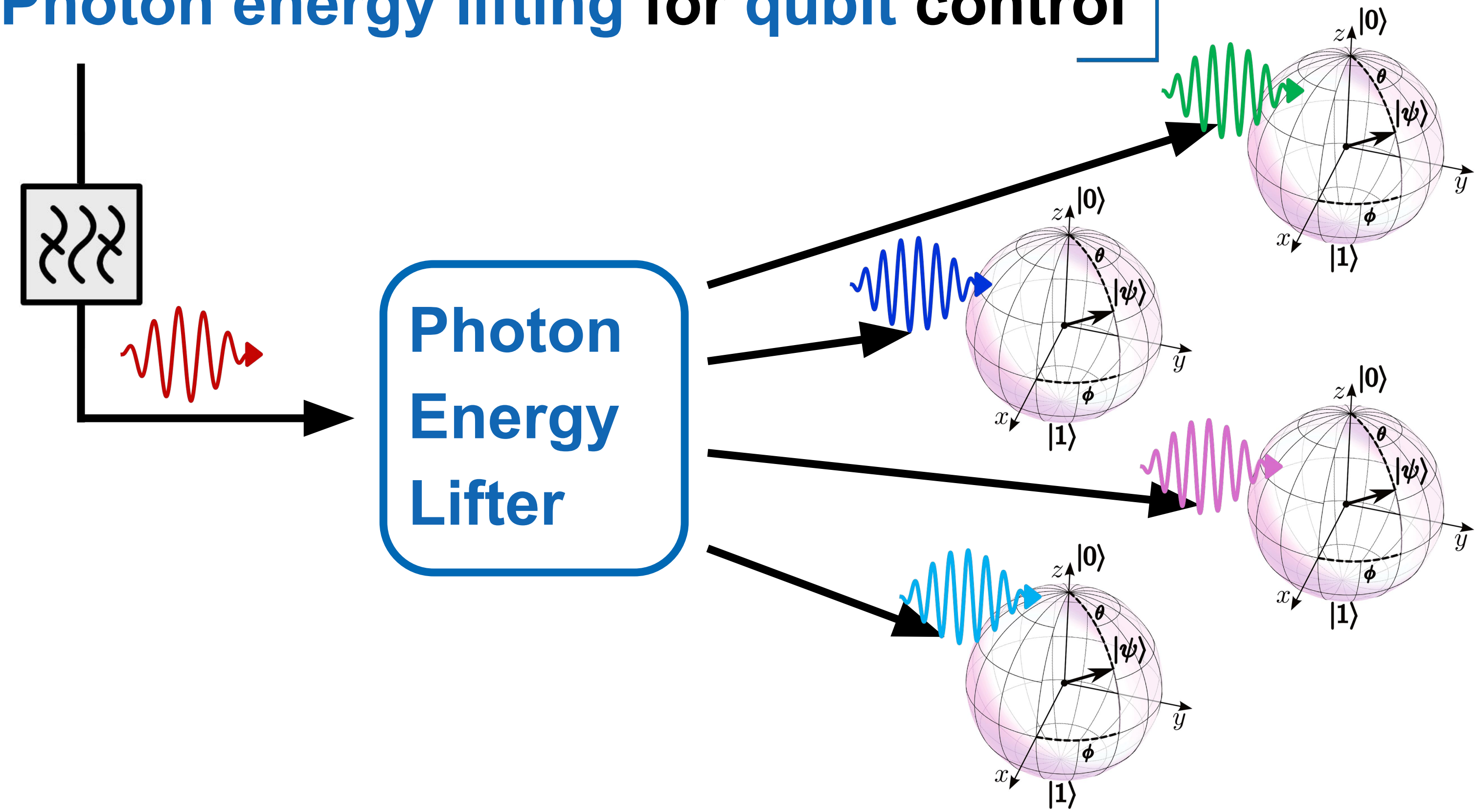
Felix Ahrens - TIFPA/FBK

QUART&T Kick-off 21/02/2025

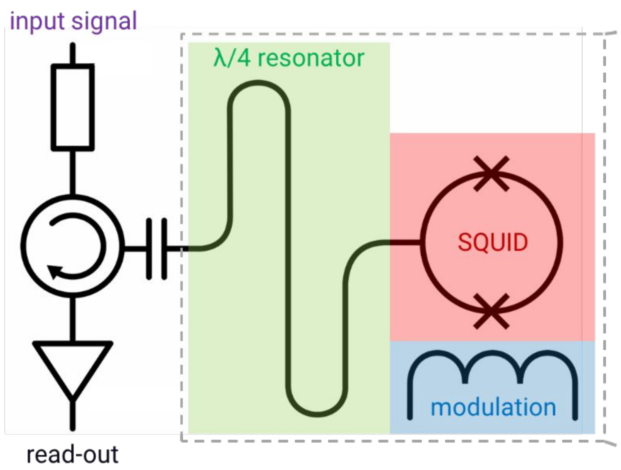
UNIVERSITÀ DI TRENTO

INFN

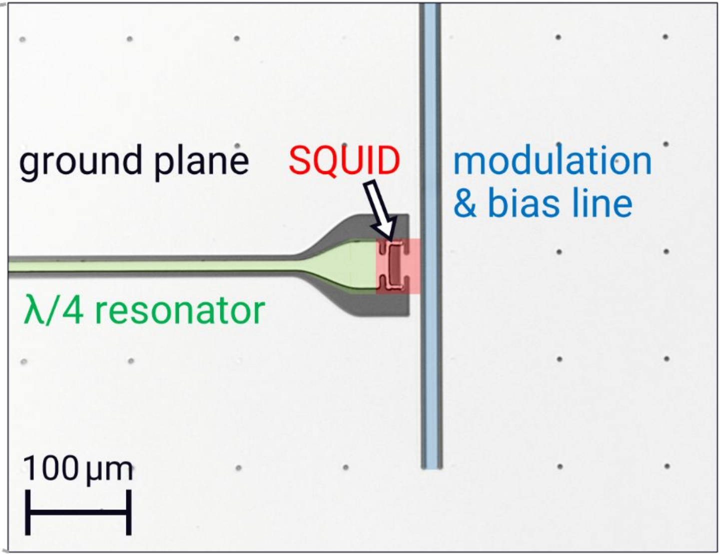
Photon energy lifting for qubit control



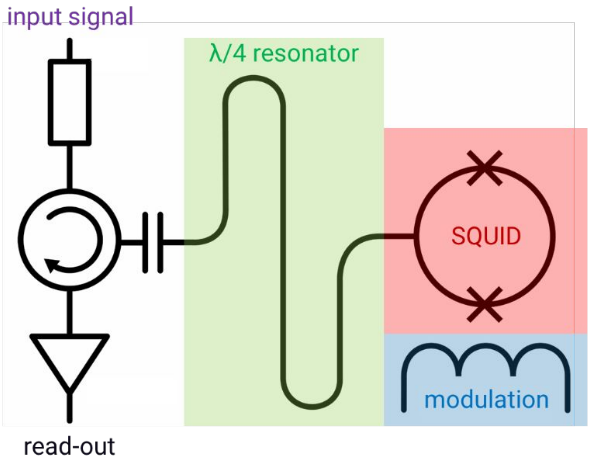
Tunable microwave cavity

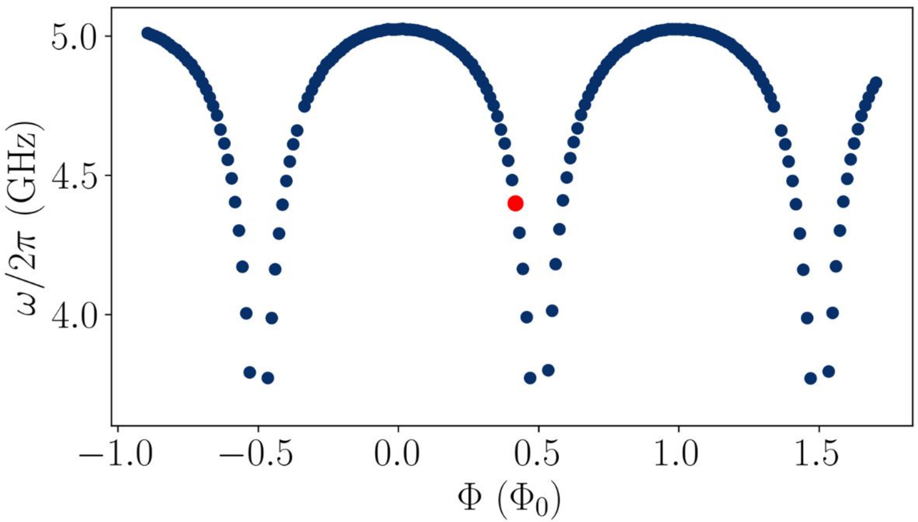


Planar tunable cavity fabricated @ FBK



Tunable microwave cavity

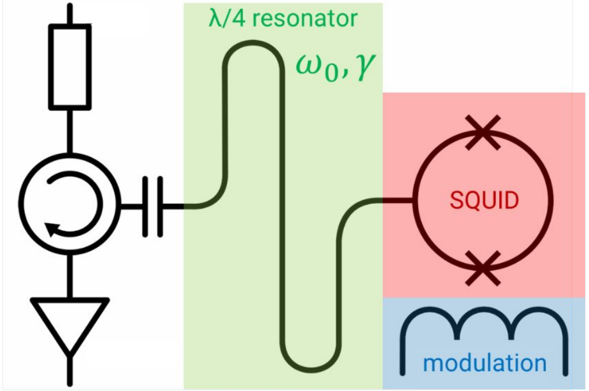




Tunable microwave cavity

$$E_{\mathrm{in}}(t) = E_{\mathrm{in}} e^{-i\omega_{\mathrm{in}} t}$$

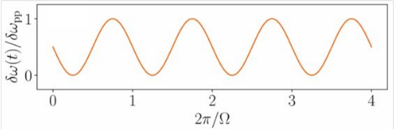
input signal

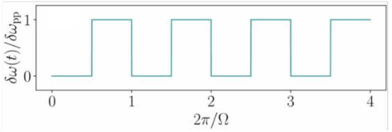


read-out

$$i\dot{\alpha}(t) = \left[\omega_0 + \delta\omega(t) - i\frac{\gamma}{2}\right]\alpha(t) + E_{\mathrm{in}}(t)$$

$\delta\omega(t) = \sum_m \delta\omega_m e^{-im\Omega t}$ with $\Omega \ll \omega_{\mathrm{in}}$

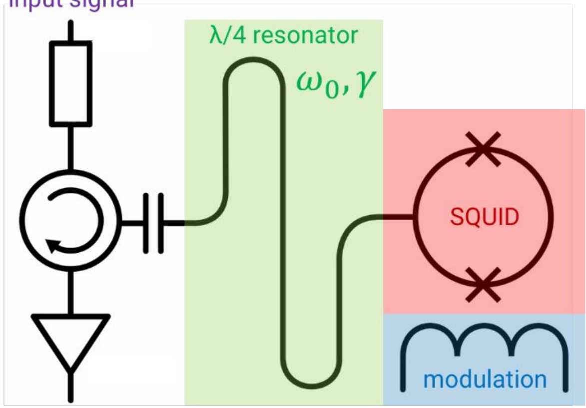




Tunable microwave cavity

$E_{\text{in}}(t) = E_{\text{in}} e^{-i\omega_{\text{in}} t}$

input signal



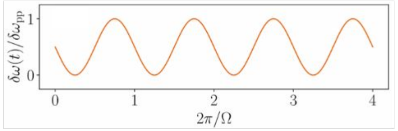
read-out

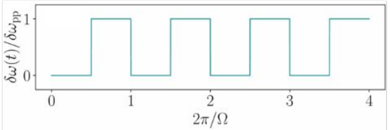
$$i\dot{\alpha}(t) = \left[\omega_0 + \delta\omega(t) - i\frac{\gamma}{2}\right]\alpha(t) + E_{\text{in}}(t)$$

Ansatz: $\alpha(t) = \sum_n \alpha_n e^{-i(\omega_{\text{in}} + n\Omega)t}$

$$\boxed{\left[\omega_{\text{in}} - (\omega_0 - n\Omega) + i\frac{\gamma}{2}\right]\alpha_n - \sum_m \delta\omega_m \alpha_{n-m} = E_{\text{in}}\delta_{n,0}}$$

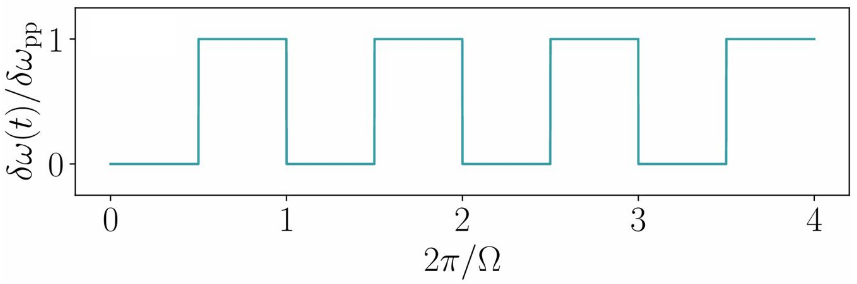
$\delta\omega(t) = \sum_m \delta\omega_m e^{-im\Omega t}$ with $\Omega \ll \omega_{\text{in}}$

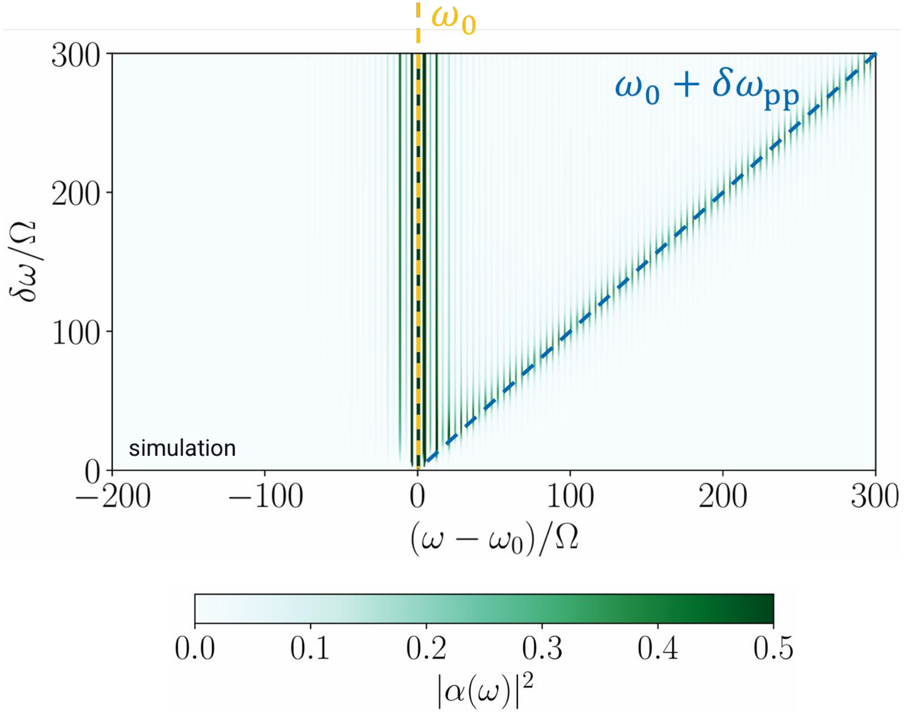




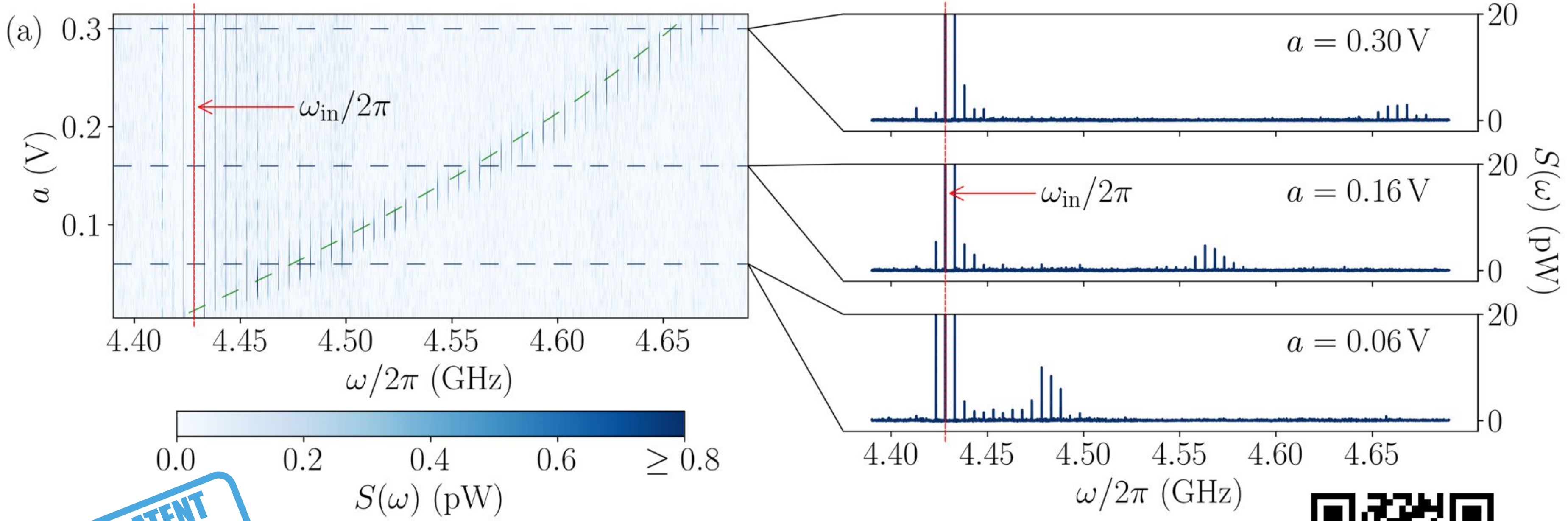
Tuning the cavity faster than the photon lifetime

$$i\dot{\alpha}(t) = \left[\omega_0 + \delta\omega(t) - i\frac{\gamma}{2}\right]\alpha(t) + E_{\text{in}}(t)$$





Experimental results: sweeping the modulation amplitude



PATENT PENDING

Amplitude controlled frequency shifter

arxiv:2409.00760

Towards a more powerful photon energy lifter

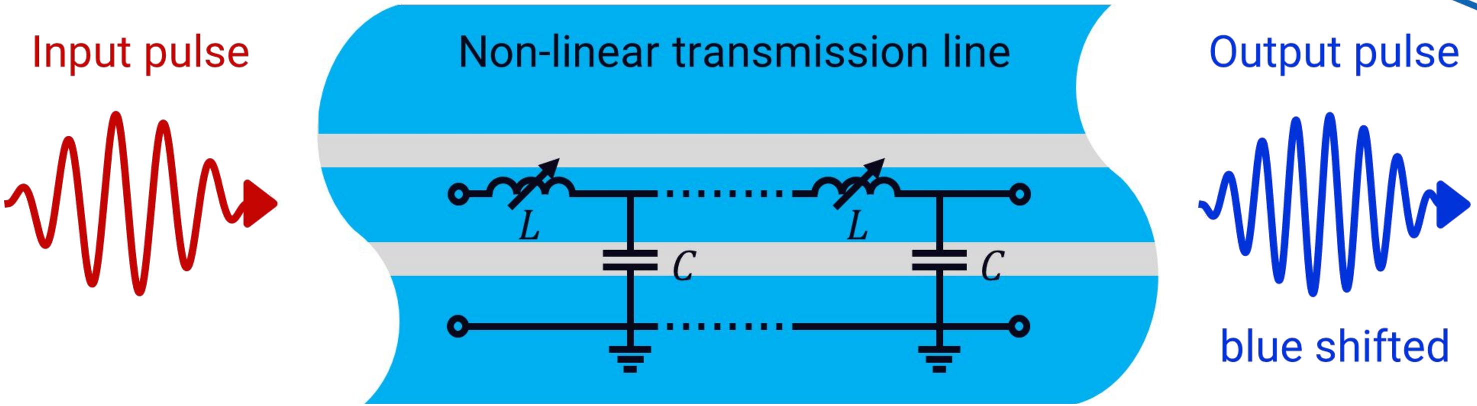
Challenges:

- Resonant, narrow band lifter → broadband lifter
- CW / engineered pulse shape → pulse shape preserving

⇒ **Travelling Wave Photon Energy Lifter (TWPEL)**

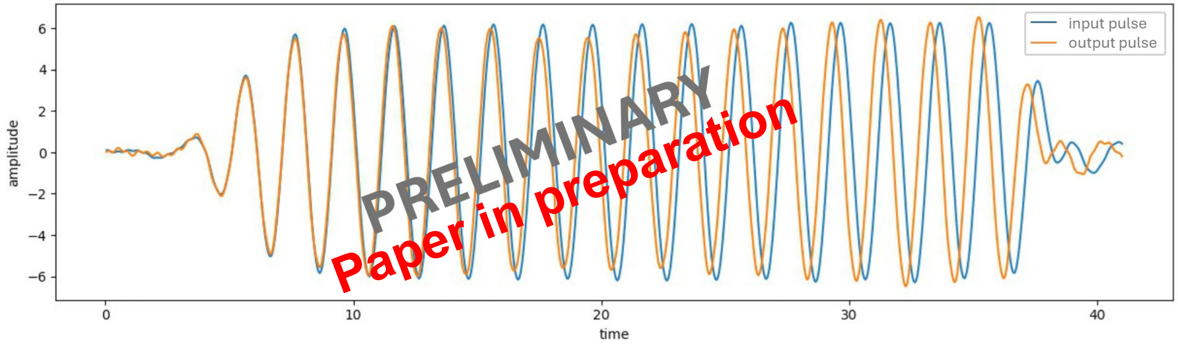
Travelling wave photon energy lifter

PATENT IN PREPARATION



Travelling wave photon energy lifter

Measurements ongoing!



Challenges:

- Dedicated dispersion engineering
- Sufficient tunability and non-linearity

Travelling Wave Photon Energy Lifter for QUART&T

Questions:

- Which **experiments within QUART&T** would benefit from TWPELs?
- Which **frequency range** is required?
- Which **pulse lengths** are desired?