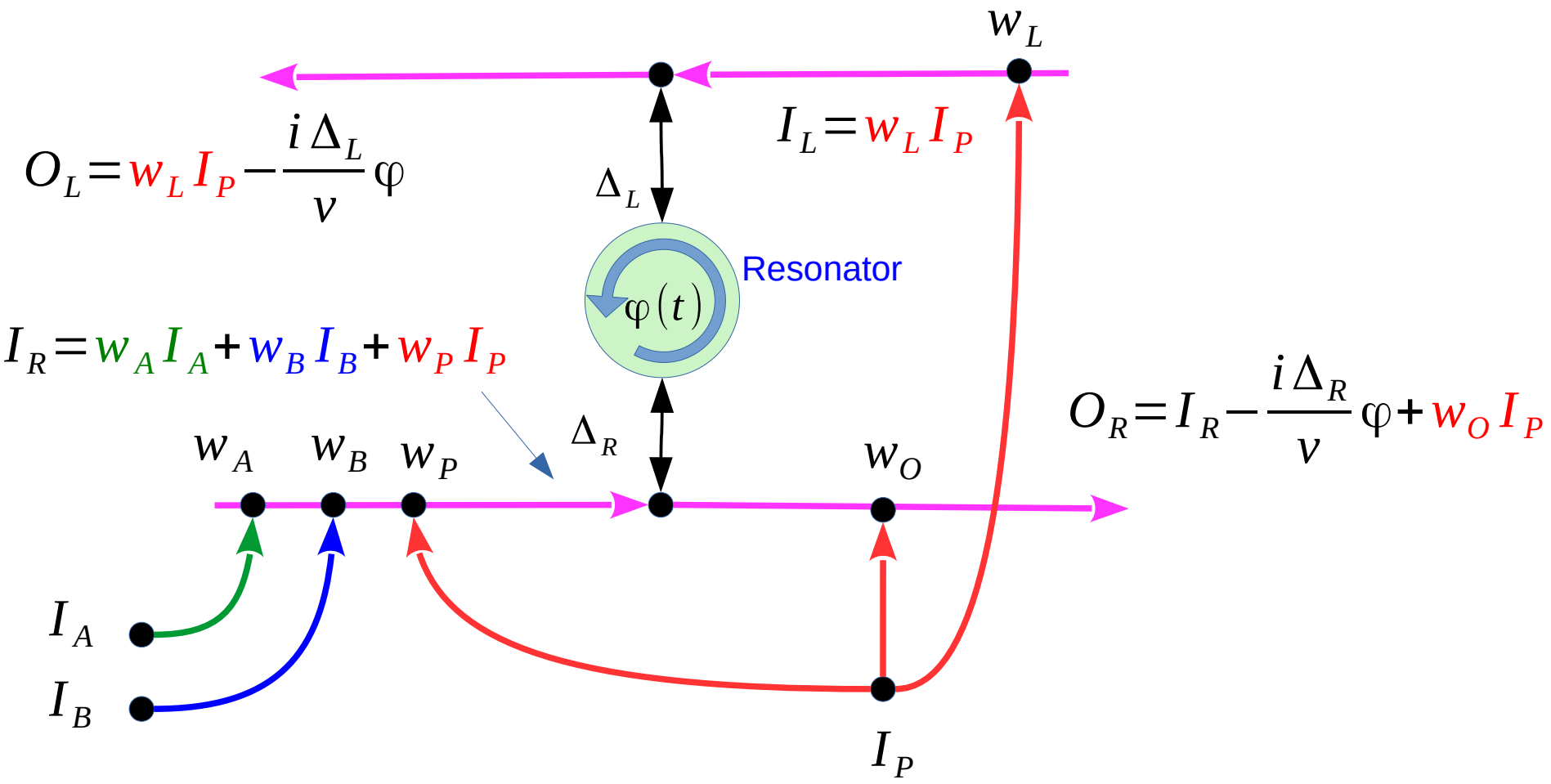
Gate with a single resonator: circuitry



Analytical model

Resonator inputs: $I_R = w_A I_A + w_B I_B + w_P I_P$

$I_L = w_L I_P$

Logical

Power input (bias)

Outputs: $O_L = w_L I_P - \frac{i\Delta_L}{\nu}\varphi$

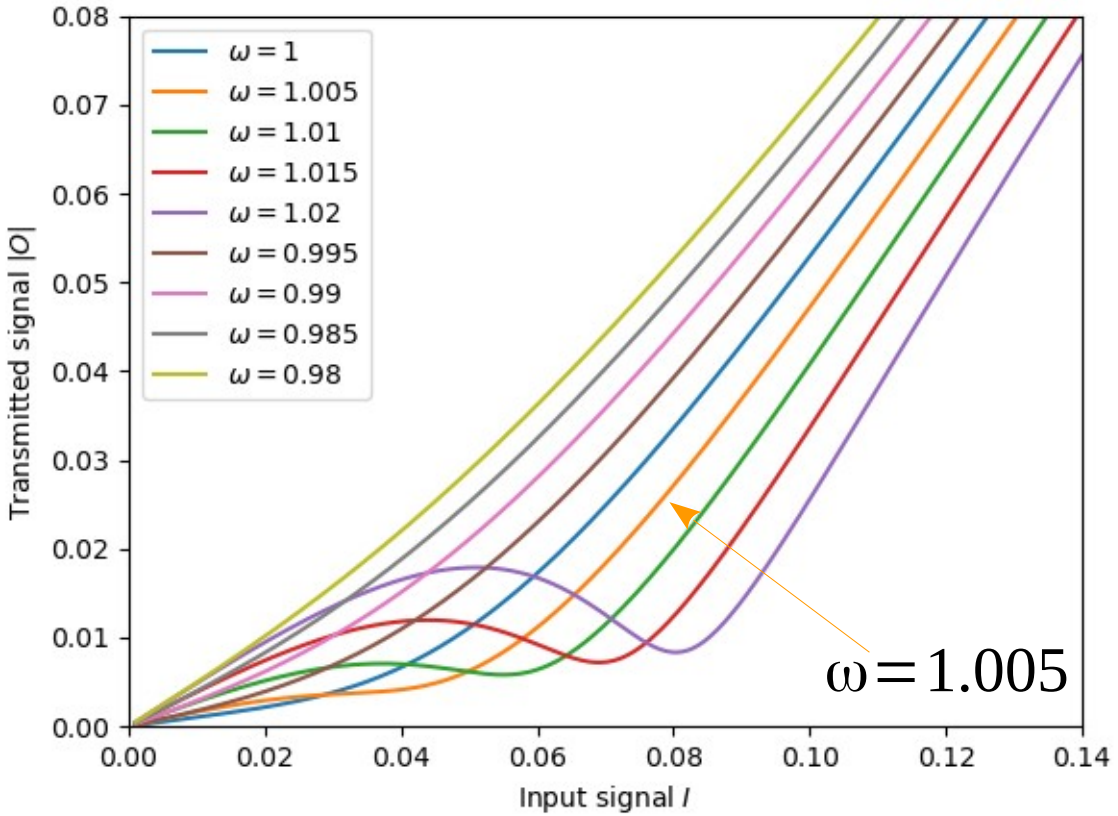
Gate output → $O_R = I_R - \frac{i\Delta_R}{\nu}\varphi + w_O I_P$

Dynamics: $\left(\omega - \Omega_0 + i\Gamma_{\text{tot}} - \lambda|\varphi|^2\right)\varphi = \Delta_R^* I_R + \Delta_L^* I_L$ $\qquad \Gamma_{\text{tot}} \equiv \Gamma_0 + \frac{|\Delta_R|^2}{2\nu} + \frac{|\Delta_L|^2}{2\nu}$

Resonator params (real): $\Omega_0, \Gamma_0, \lambda$ Hybridisation (complex): Δ_R, Δ_L

Circuitry params (complex-valiued!): $w_A, w_B(=w_A), w_P, w_O, w_L$

Case study: resonator



Resonator params:

$\Omega_0 = 1.0 \quad \Gamma_0 = 0.005 \quad \lambda = 0.1$

$v = 1.0 \quad \Delta_R = 0.2 \quad \Delta_L = 0.15$

$\Gamma_R = 0.02 \quad \Gamma_L = 0.01125$

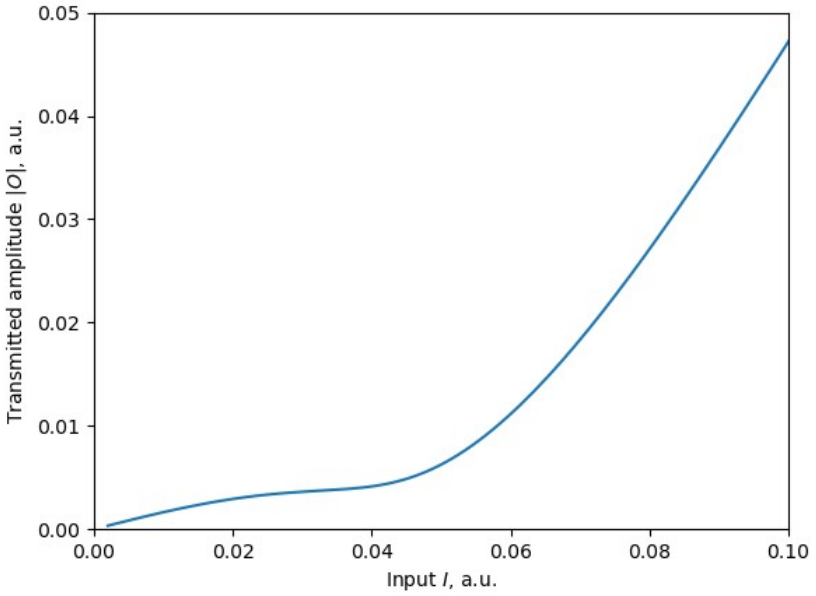
$\Gamma_{tot} = 0.03625$

Characteristic scale $I, O \sim 0.05$

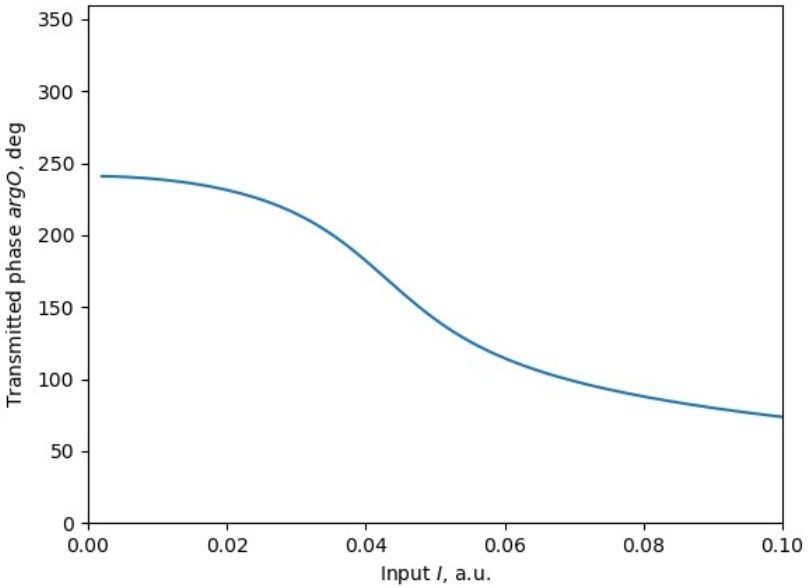
Operating frequency $\omega = 1.005$

Case study: activation function

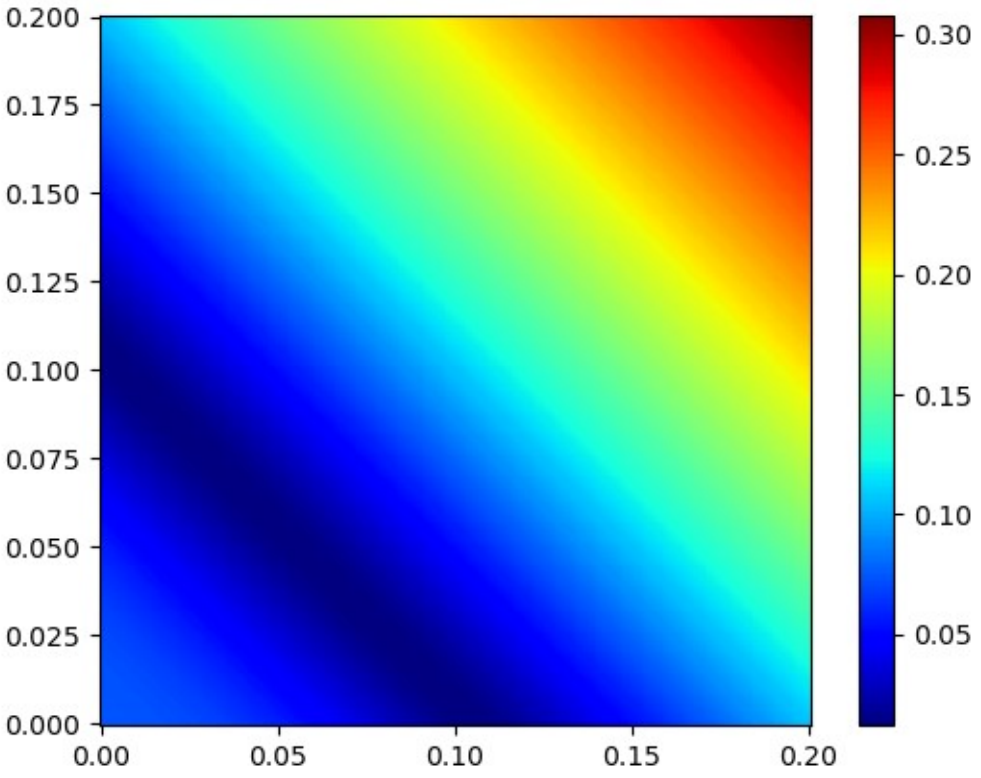
Amplitude response @ 1.005



Phase @ 1.005



Case study: Example output (analogue)



Circuitry:

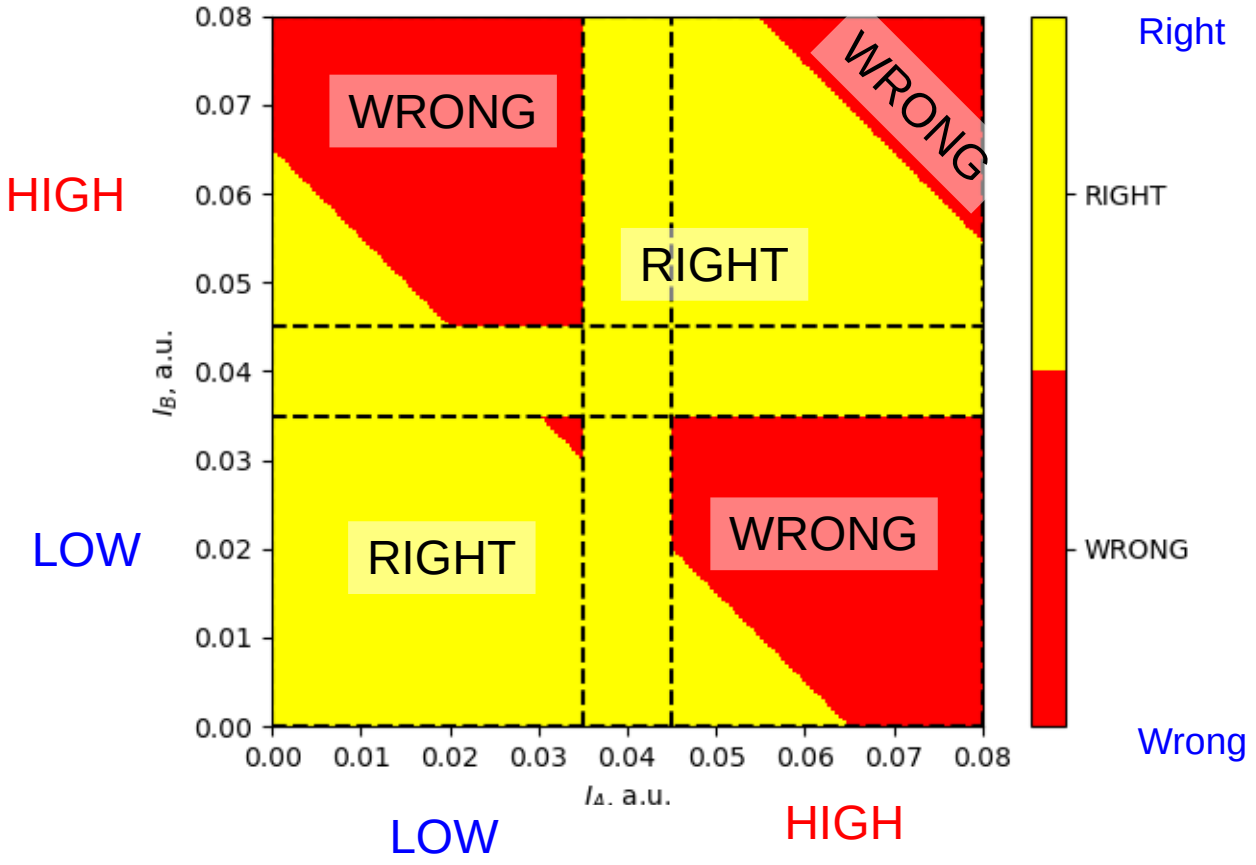
$$w_A = w_B = 0.9 \quad w_P = 0.2$$

$$w_O = 0.5i \quad w_L = -0.5i$$

$$I_P = 0.08$$

NAND-like behaviour for I < 0.1?

Digital performance: fidelity as NAND



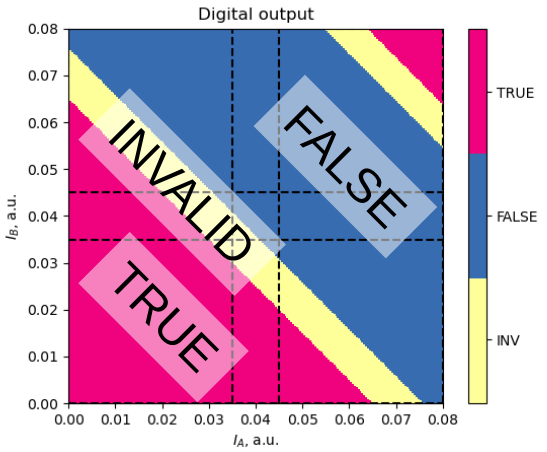
Logical levels:

$0.0 < \mathrm{LOW} < 0.035$

$0.045 < \mathrm{HIGH} < 0.08$

OTHERWISE: INVALID

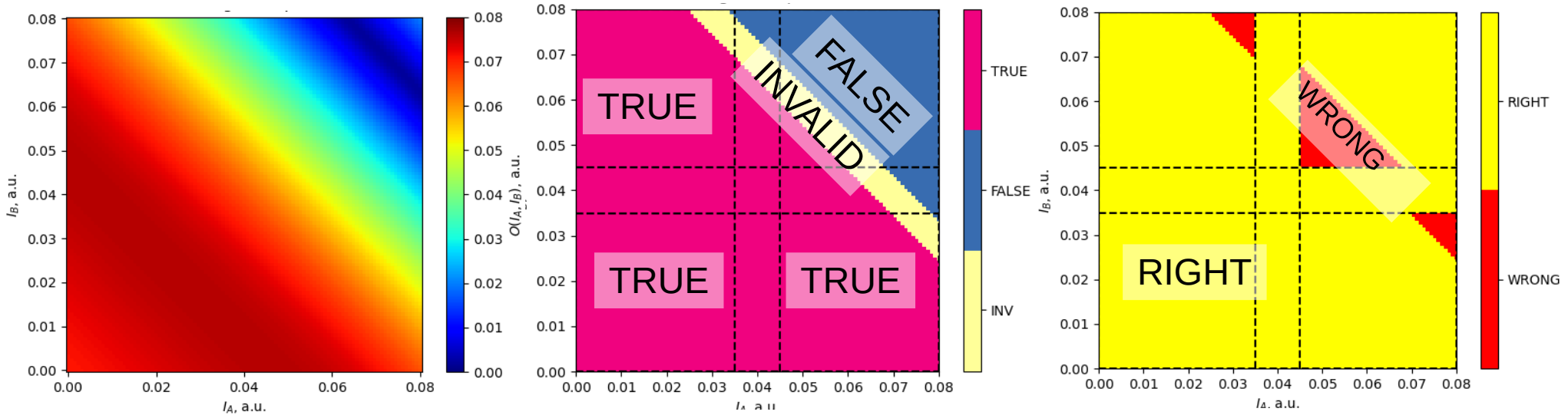
Performance metric:
Minimal WRONG area



Optimization (via differential evolution, with phases):

$$w_A = w_B = 0.977679, \quad w_P = -0.166609 - 0.112921\,i$$

$$w_L = -0.077261 + 0.360543\,i, \quad w_O = -0.362986 - 0.585067\,i$$



Obstacle: diagonality, dependence upon the linear combination $w_A I_A + w_B I_B$

Plan

- The weights on the gate (and other params) can be optimized
- Ditto operating freqiuency, etc

Difficulties:

- ``Diagonal'' dependence: A + B enters trivially, poor approximation for logical gates
- Fidelity/score is not smooth (changes in steps), gradient-based algorithms are not directly applicable