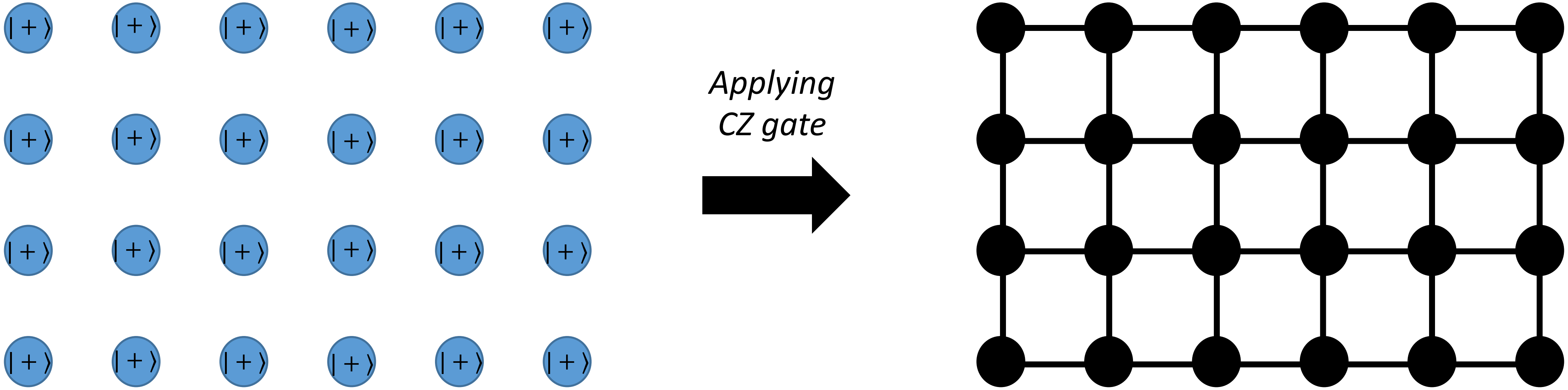
Photonic approach for implementing Quantum Computer

KLM protocol (CBQC)

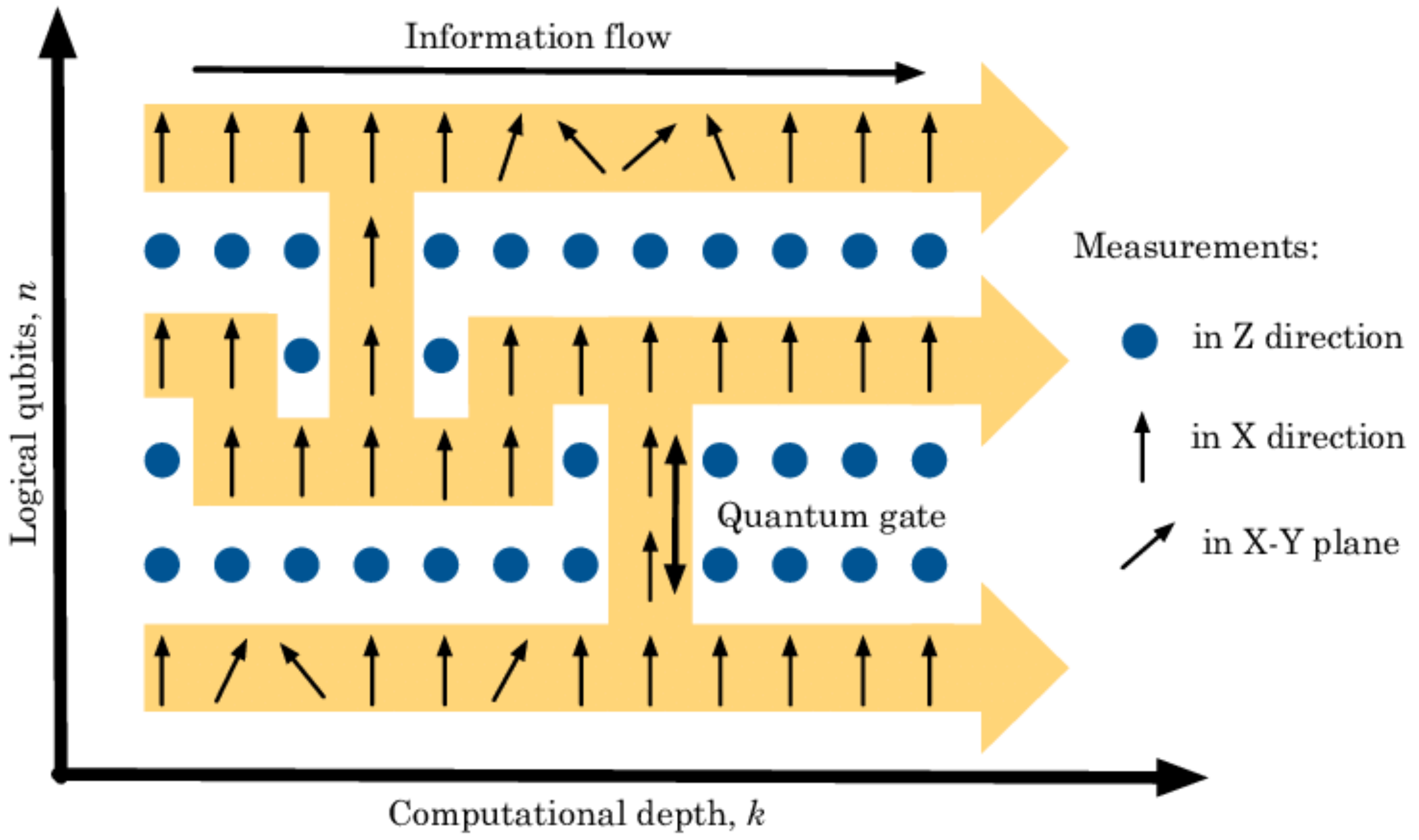
Due to restrictions of bosonic systems, it was believed that it is not possible to build a universal quantum computer using only linear optics, until in 2001, Knill, Laflamme and Milburn(KLM) realized that measurement on parts of the circuit can be used to evoke nonlinearity and still deliver scalability.

Measurement based quantum computation(MBQC)

$$|+\rangle = \frac{1}{\sqrt{2}}(|0\rangle + |1\rangle)$$

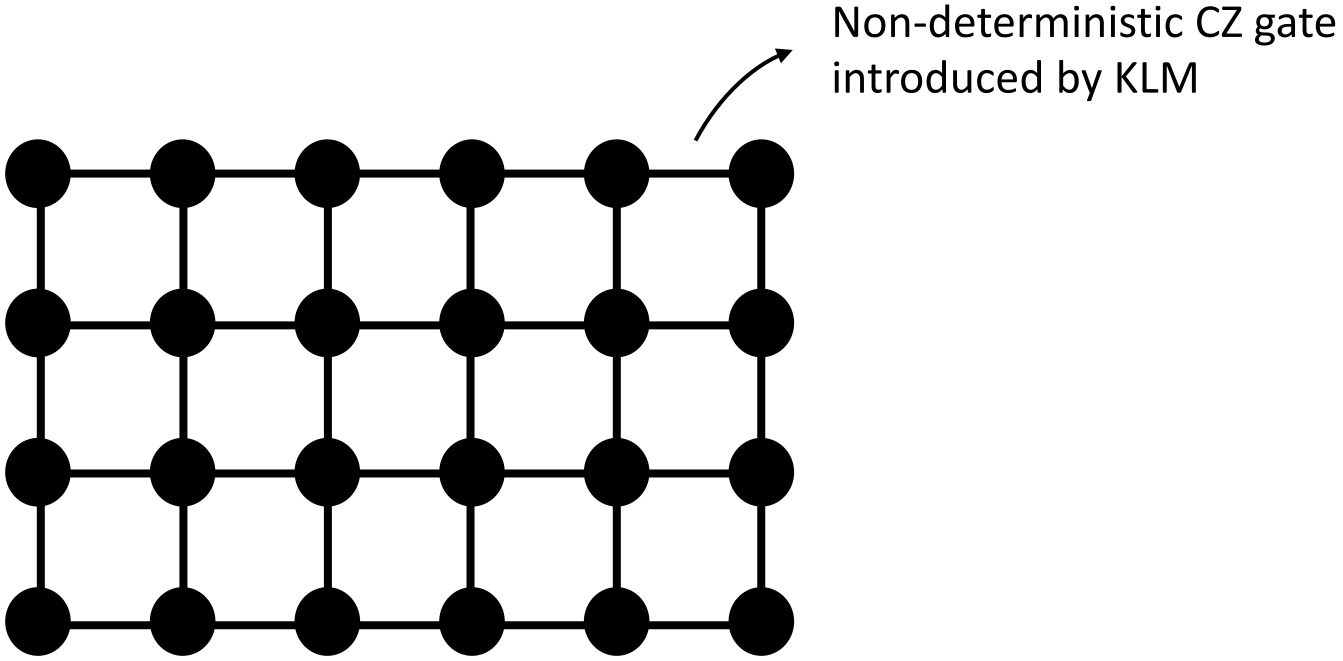


Computation on Cluster states



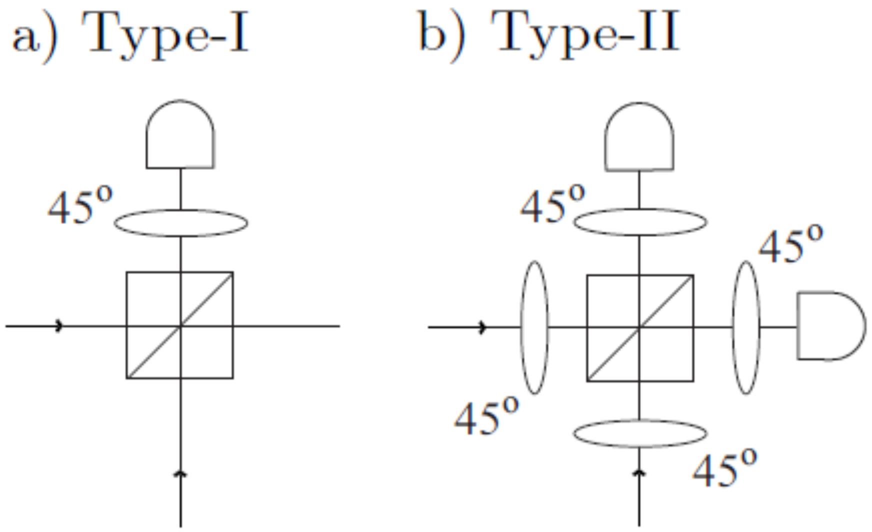
Nielsen Protocol

Nielsen introduced a protocol for generating cluster states using the probabilistic KLM CZ gate.



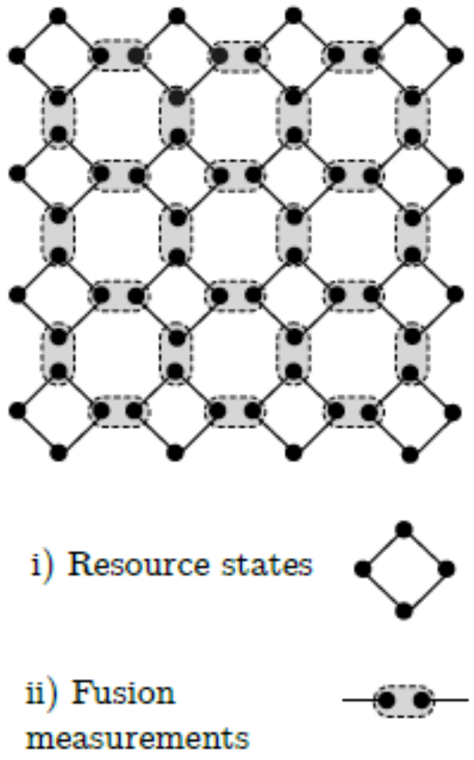
Brown-Rudolph Protocol

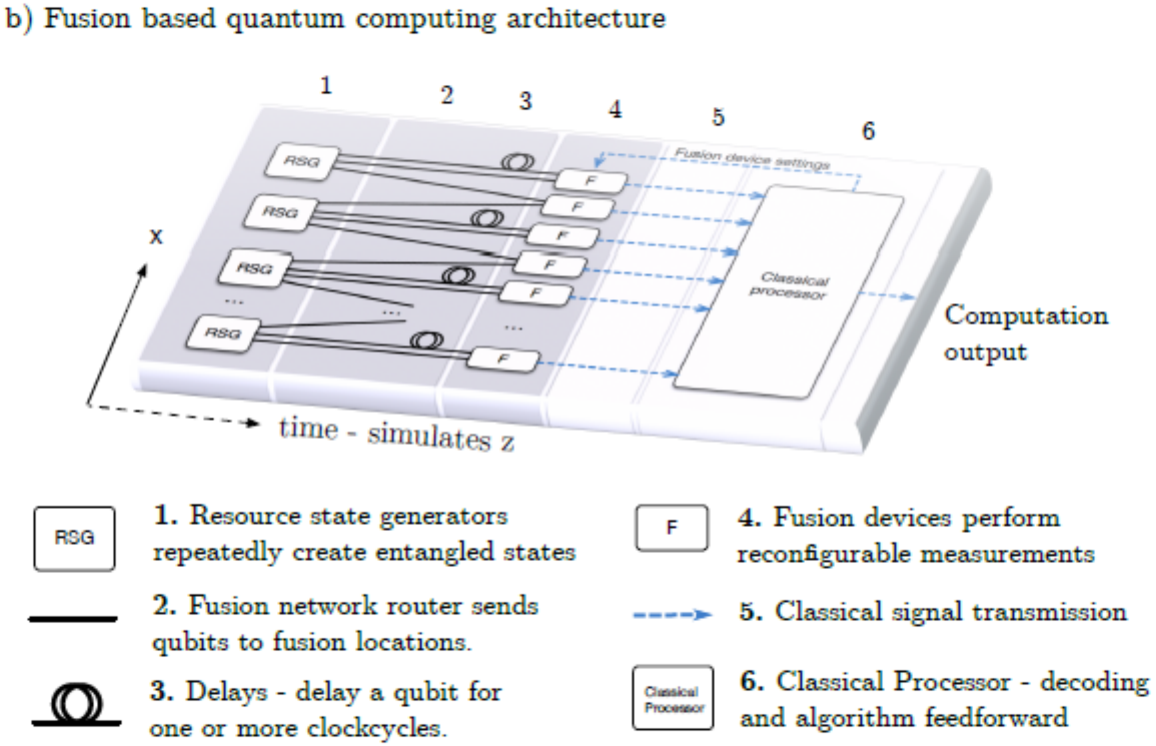
Browne and Rudolph introduced a protocol for generating cluster states using the probabilistic Fusion gate I &II.



Fault tolerant fusion based quantum computation

A model of universal quantum computation in which entangling measurements, called fusions, are performed on the qubits of small constant-sized entangled resource states.





Photonic approach and FBQC advantages

- Qubits should survive a constant depth of manipulation.
- Success of computation is independent of algorithm’s depth.
- The encoding can handle all physical error and nondeterministic nature of measurements in a fault tolerant way with a relatively high threshold for errors.
- Photons are best candidate for quantum communication so chip connectivity is mush easier, which is very good for scalability.
- No need for aggressive cooling to mK temperature.
- Manufacturing photonic chips is very compatible with already existing fabrication industry.

Disadvantages of other matter based approach

- Decoherence time!
- Lack of proper connection between far qubit on hardware, which results in implementing large number of unnecessary swap gate in algorithms.
- In matter based approaches qubits can go out of the encoded state which results in errors that can not be corrected.
- Communications between chips is still a problem.

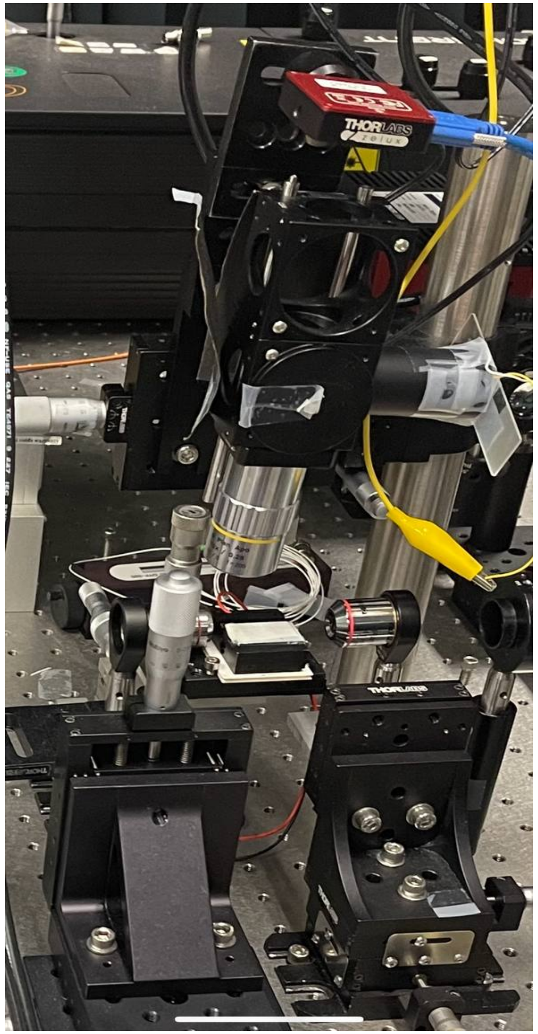
Experimental experiences

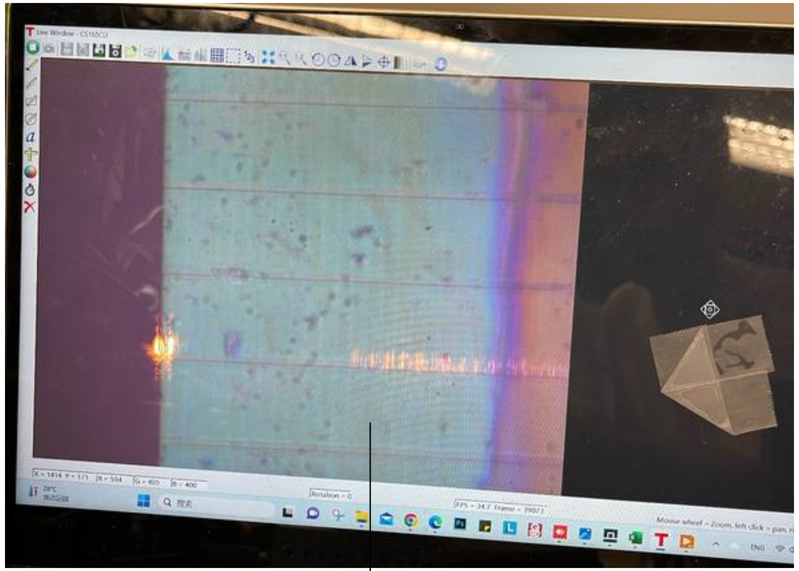
Type 0 SPDC

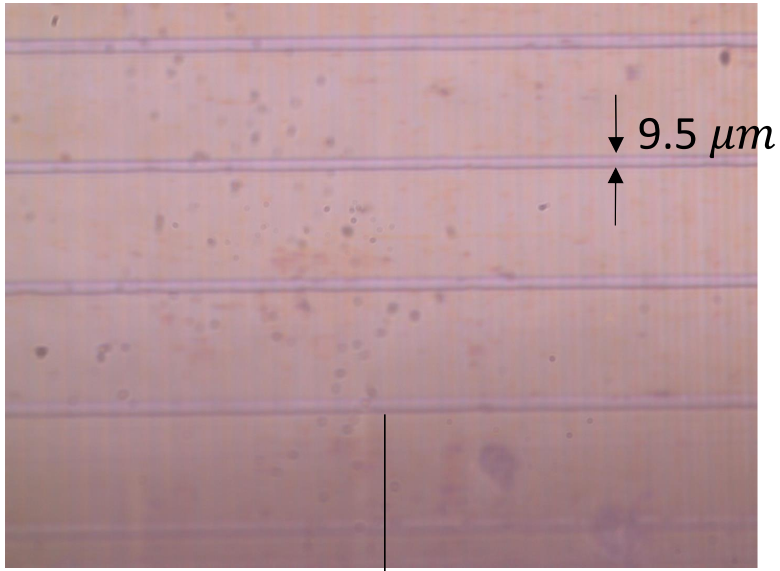
TYPE-0 ppln waveguide

5 mm

3 cm



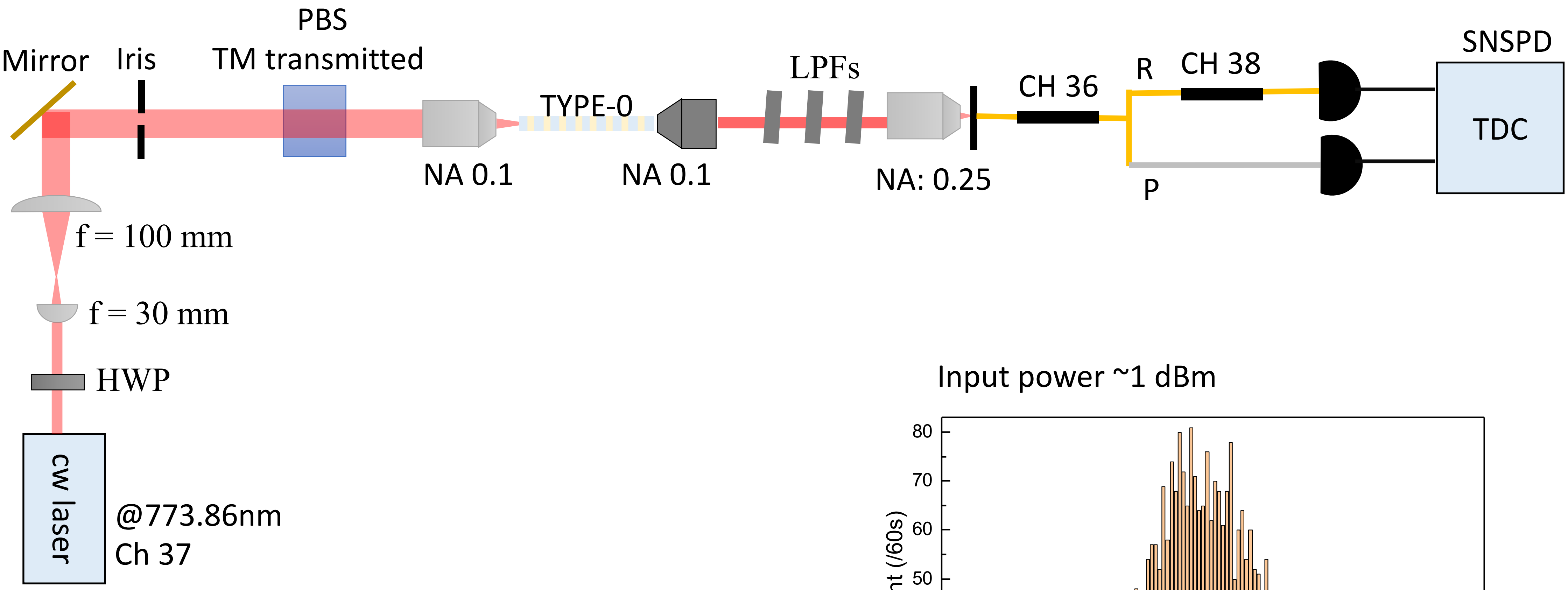




9.5 μm

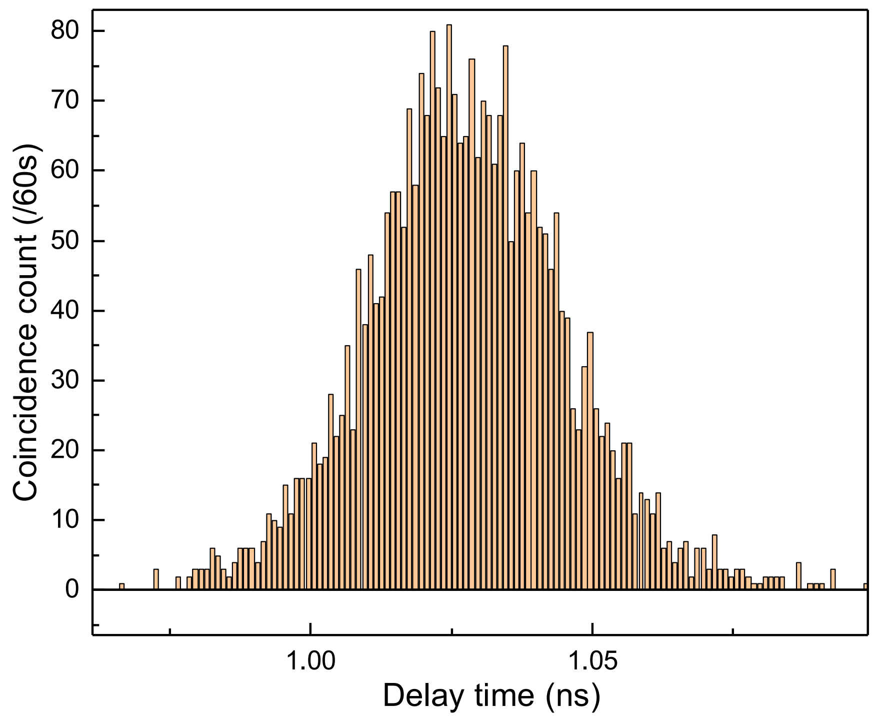
Coating

waveguide

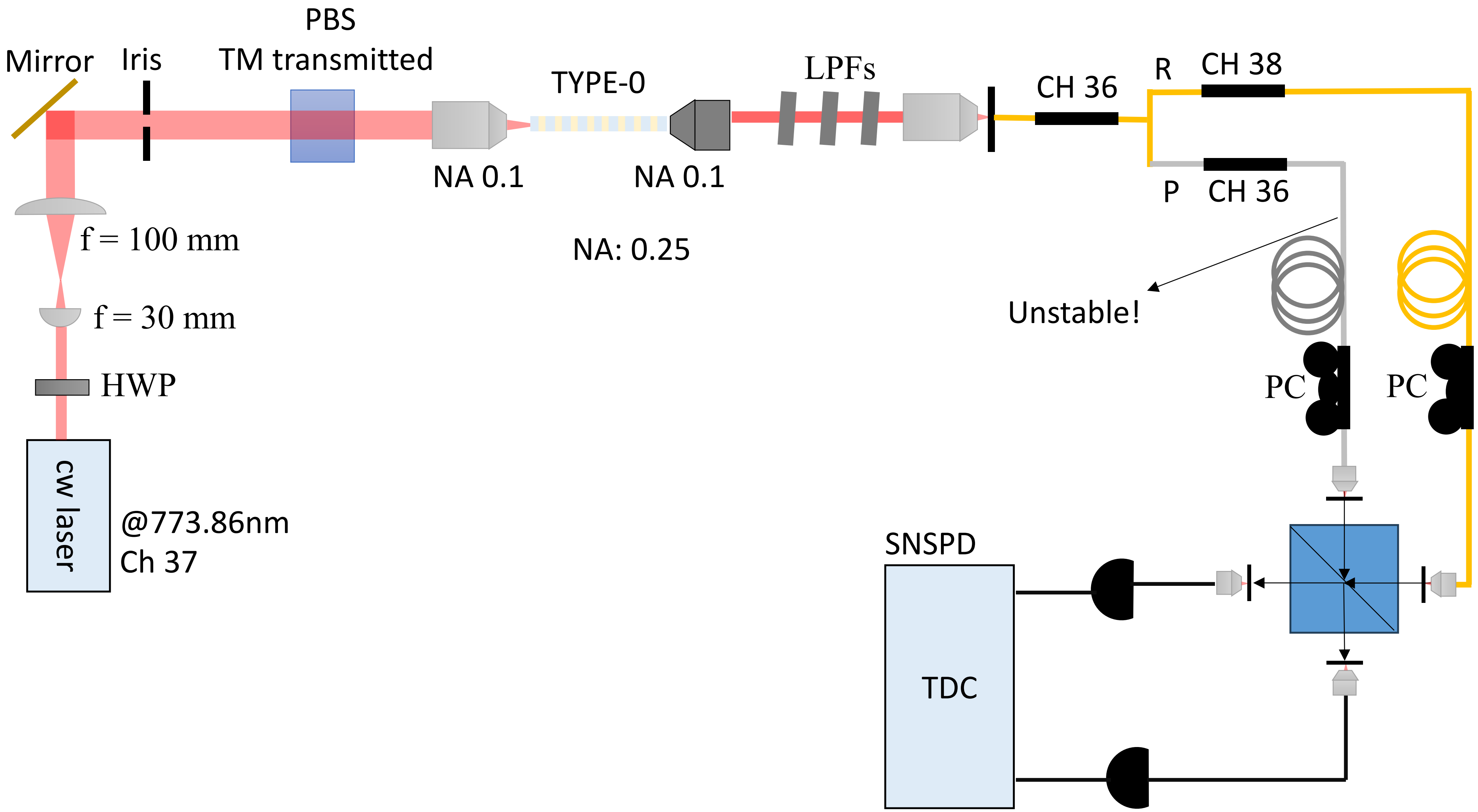


Channel	Frequency	Wavelength
#	GHz	nm
36	193600	1548.51
38	193800	1546.92

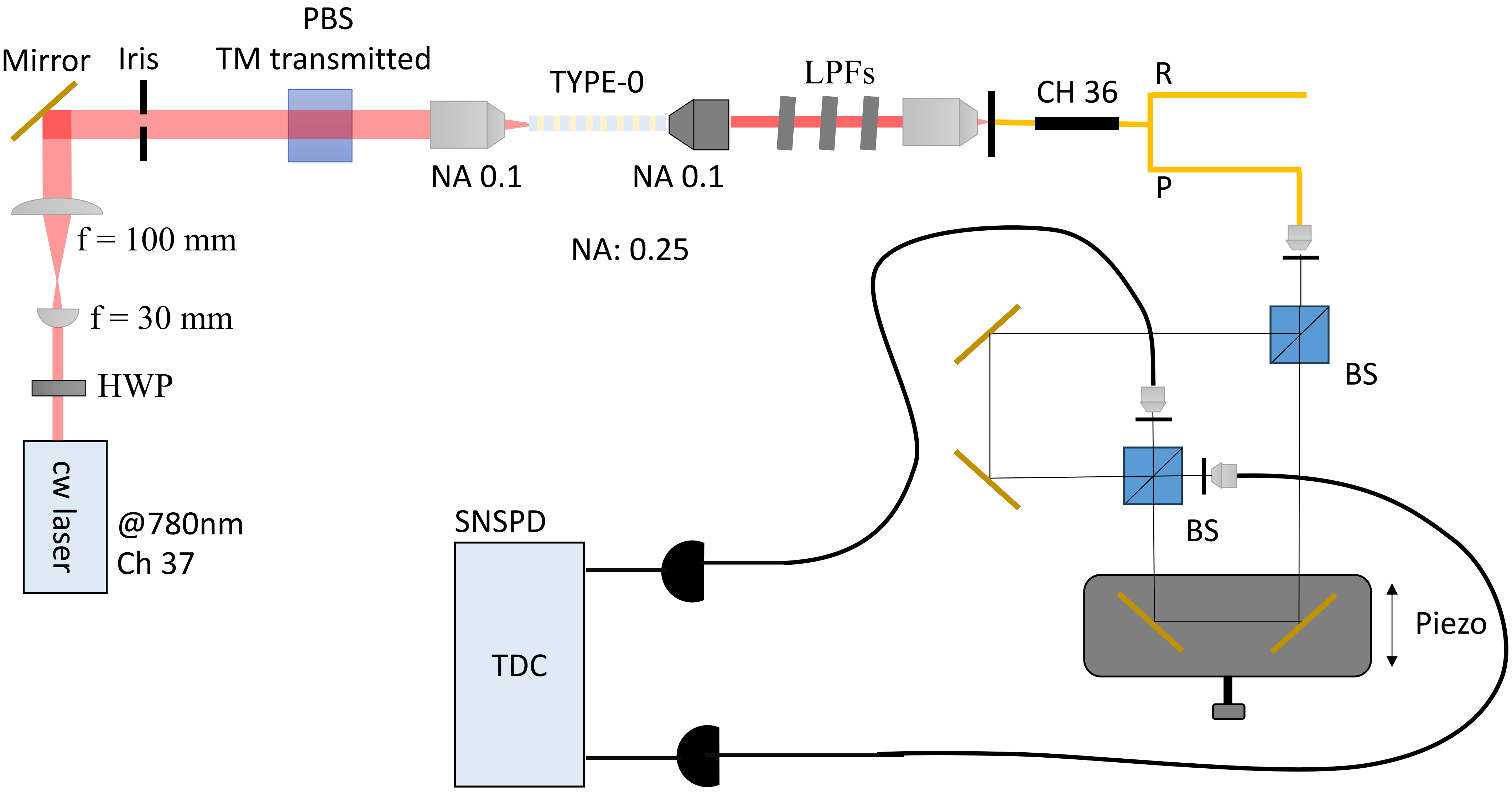
Input power ~1 dBm

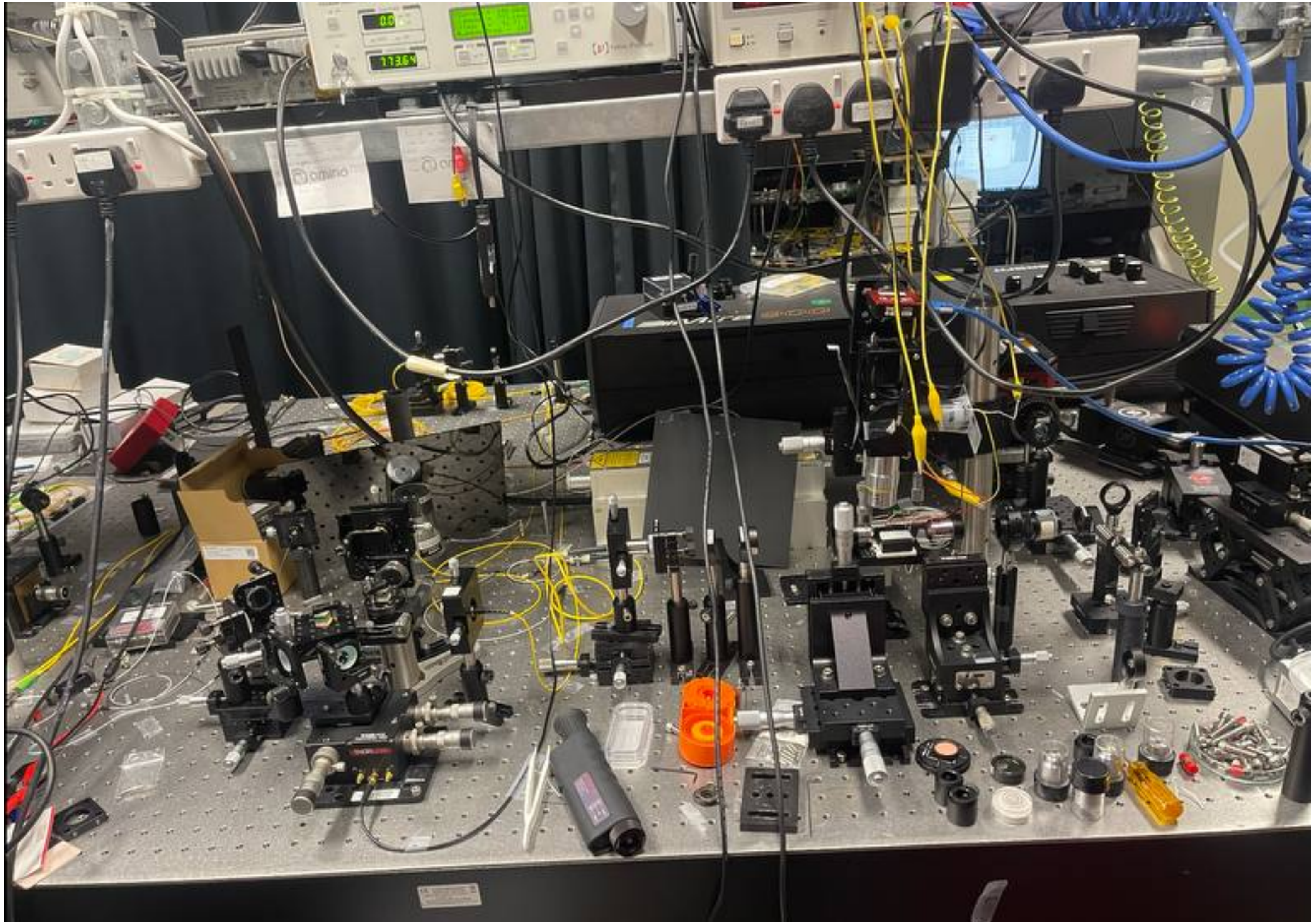


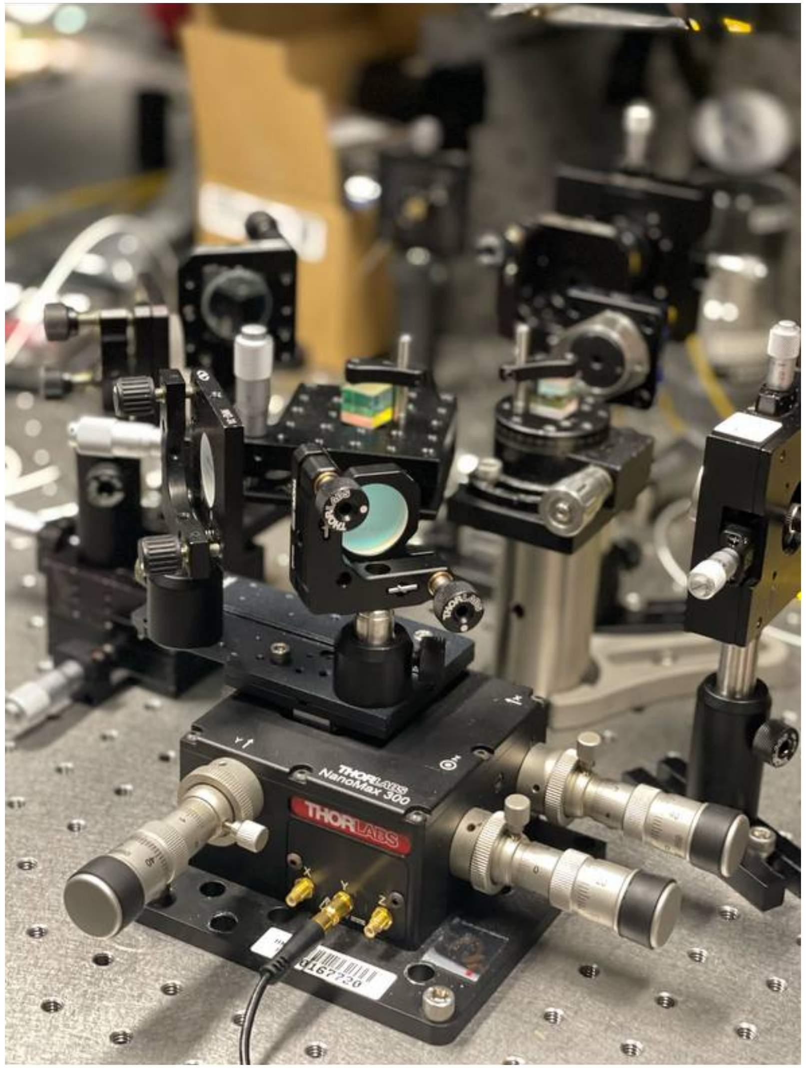
HOM interference


Mirror
Iris
PBS
TM transmitted
TYPE-0
LPFs
CH 36
R
CH 38
P
CH 36
NA 0.1
NA 0.1
NA: 0.25
f = 100 mm
f = 30 mm
HWP
cw laser
@773.86nm
Ch 37
Unstable!
PC
PC
SNSPD
TDC

Franson interference


PBS
TM transmitted
Mirror
Iris
TYPE-0
LPFs
CH 36
R
P
NA 0.1
NA 0.1
NA: 0.25
f = 100 mm
f = 30 mm
HWP
cw laser
@780nm
Ch 37
BS
BS
SNSPD
TDC
Piezo

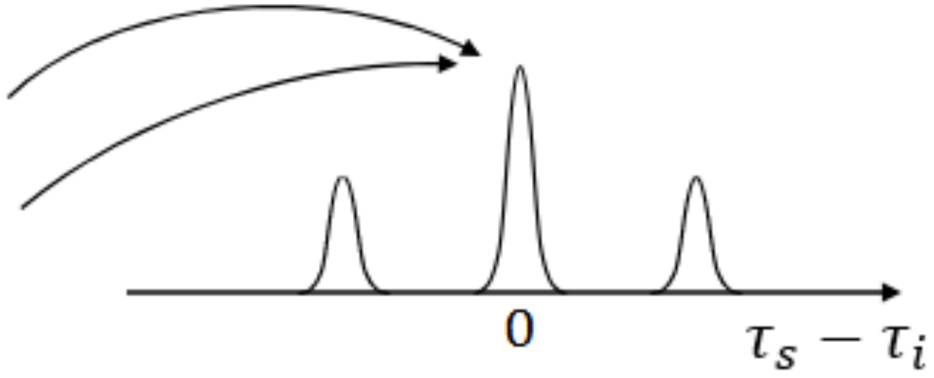


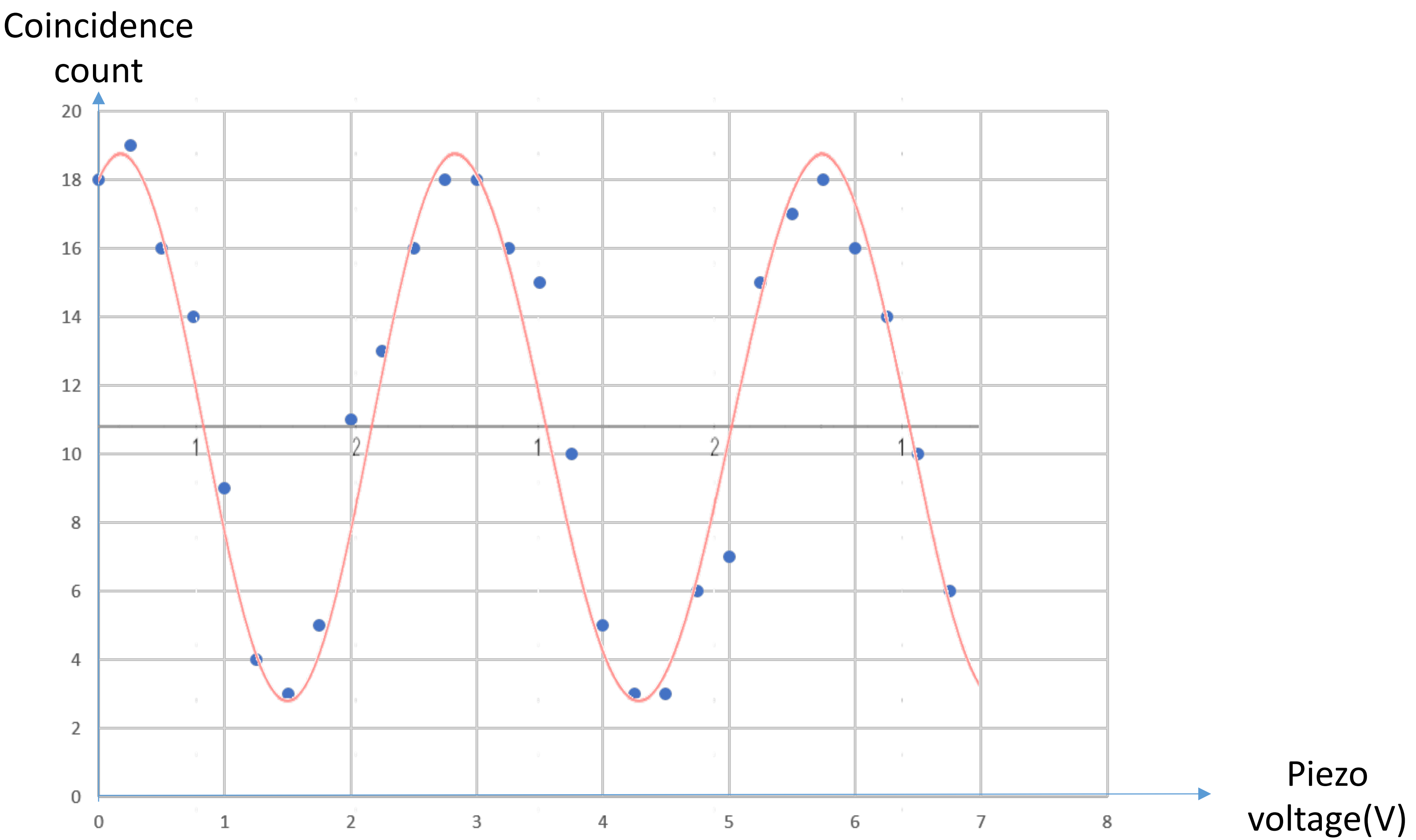

THORLABS
NanoMax 300
THORLABS


THORLABS
NanoMax 300

The states:	Delay:
$\|\psi\rangle = \|L\rangle_s \|S\rangle_i$	$-\Delta\tau$
$\|\psi\rangle = \|S\rangle_s \|S\rangle_i$	0
$\|\psi\rangle = e^{i(\varphi_s+\varphi_i)} \|L\rangle_s \|L\rangle_i$	0
$\|\psi\rangle = \|S\rangle_s \|L\rangle_i$	$\Delta\tau$

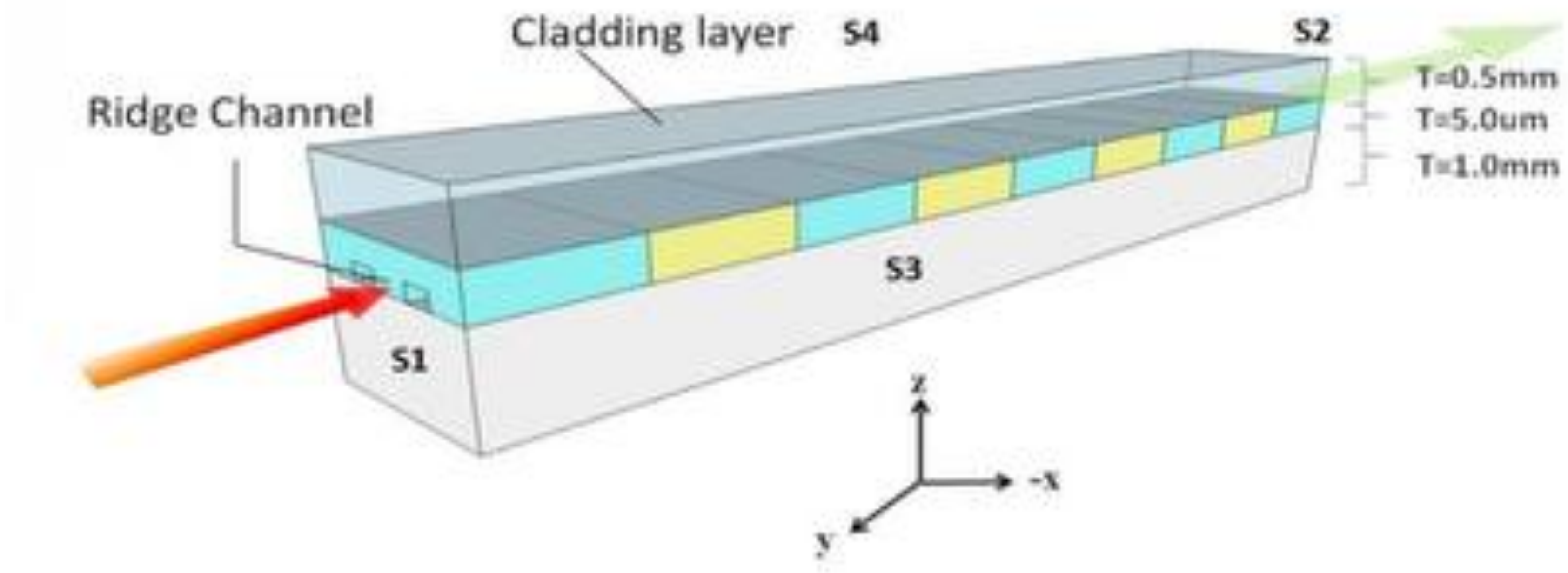
Histogram: PD2

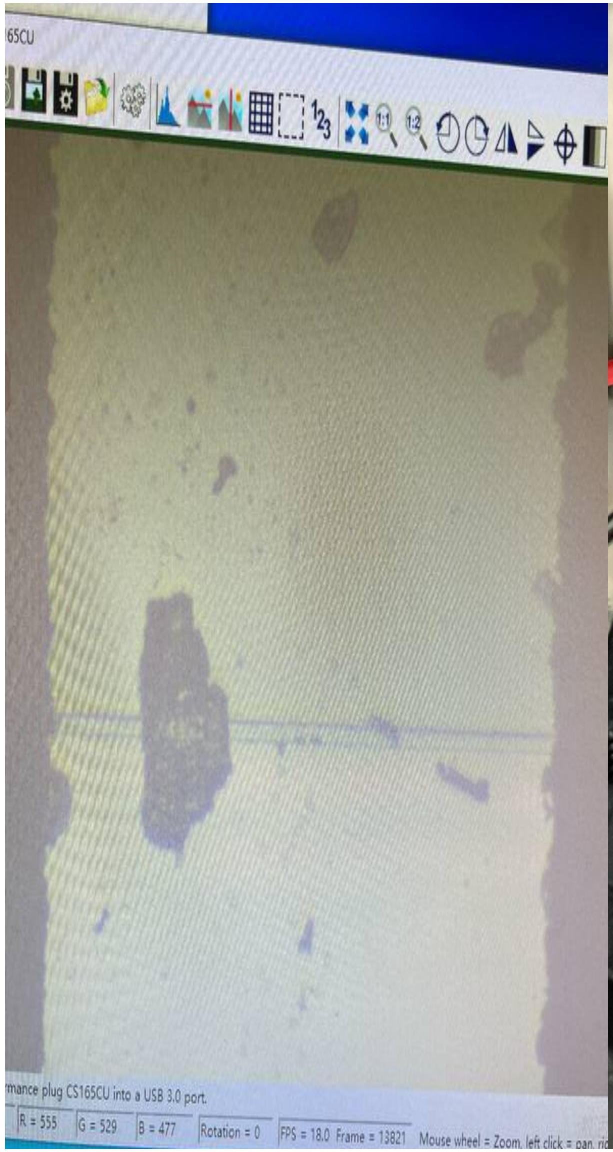



Coincidence count
20
18
16
14
12
10
8
6
4
2
0
1
2
1
2
1
0
1
2
3
4
5
6
7
8
Piezo voltage(V)

Type 2 SPDC

TYPE-2 ppln waveguide

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G = 529
B = 477
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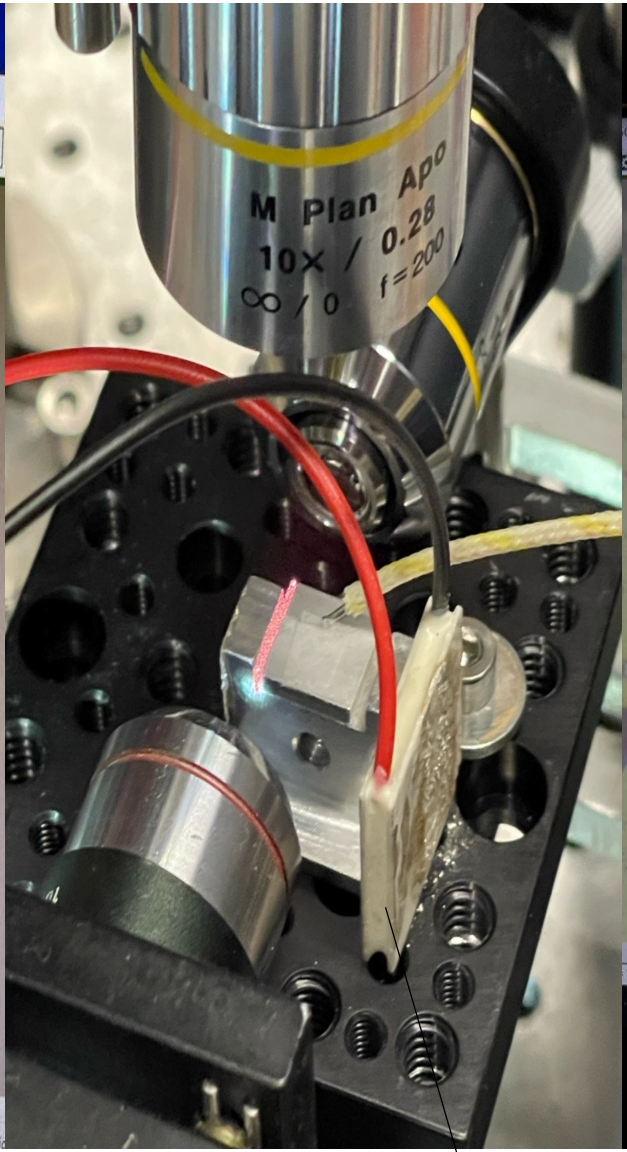
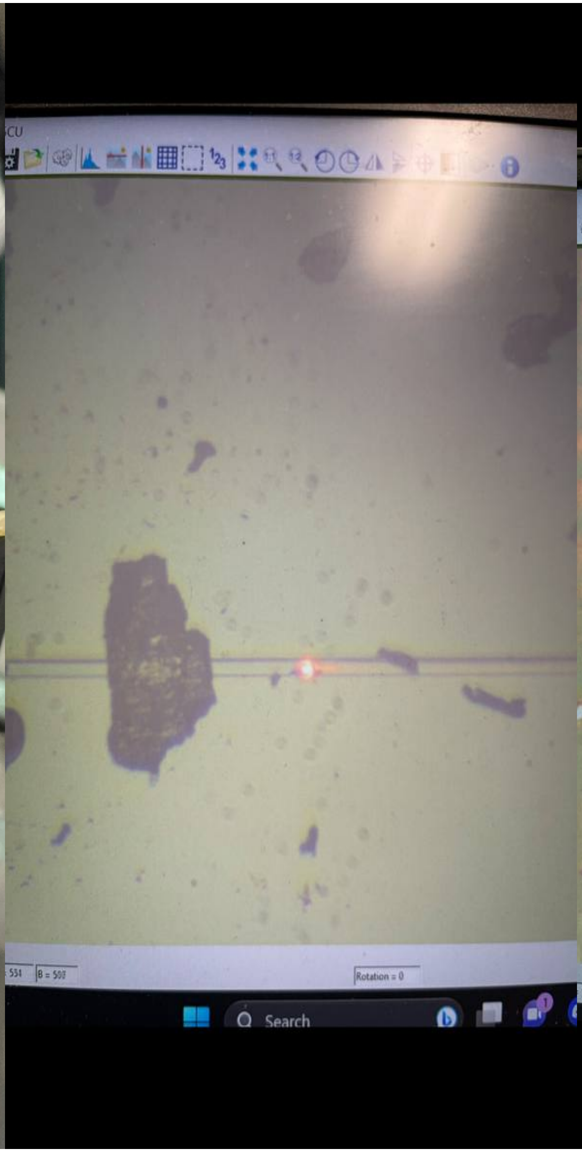
FPS = 18.0 Frame = 13821

M Plan Apo
10X / 0.28
∞ / 0 f=200

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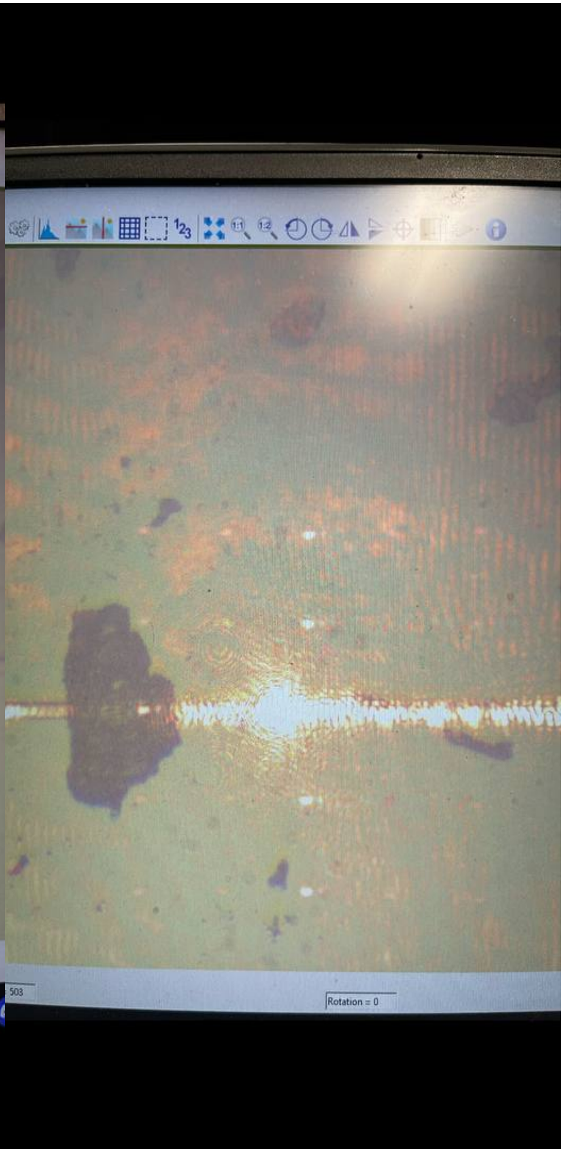
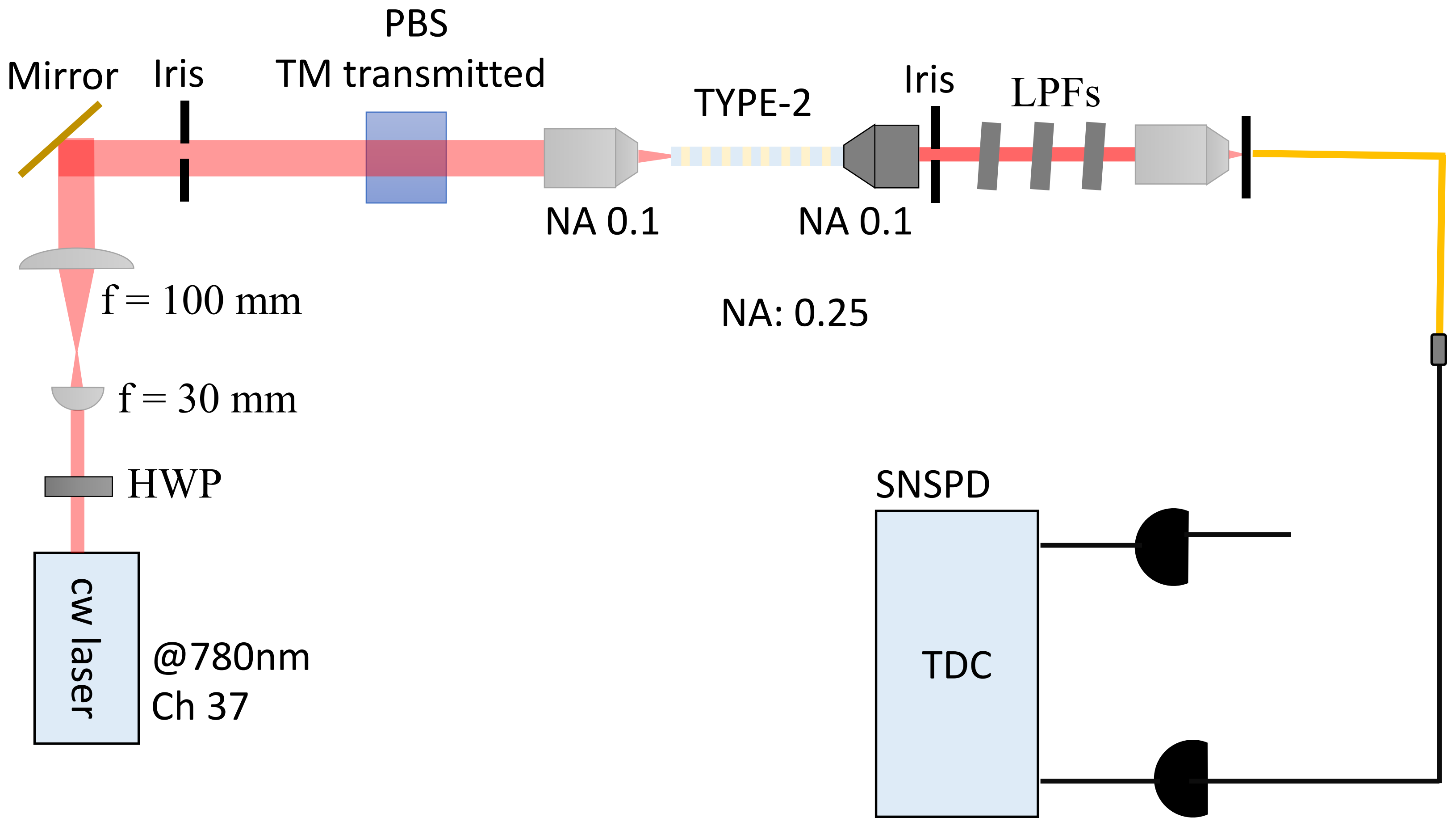
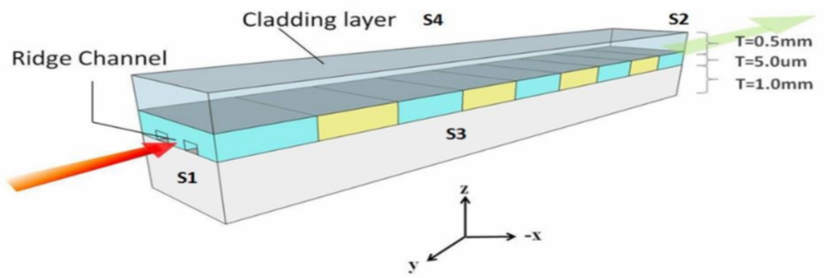
Search

Rotation = 0

TEC


PBS
TM transmitted
Mirror
Iris
TYPE-2
Iris
LPFs
NA 0.1
NA 0.1
NA: 0.25
f = 100 mm
f = 30 mm
HWP
cw laser
@780nm
Ch 37
SNSPD
TDC

HCP
HC PHOTONICS CORP.

B. Chip Physical Structure

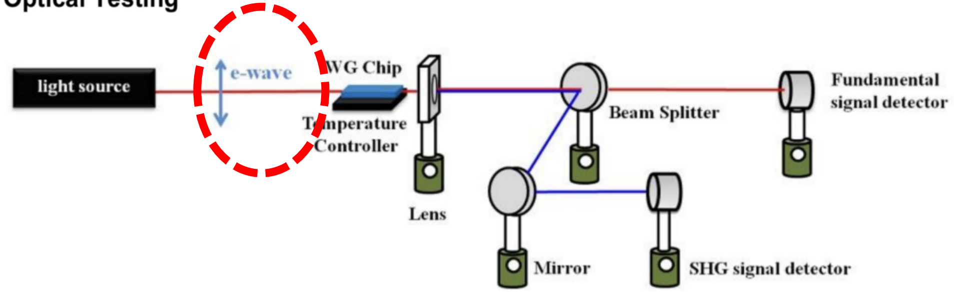


Note :

1. Please avoid moving the chip with respect to the laser beam during high power operation.
2. Please handle the chip with the S3/S4 facets and avoid contacting both input/output (S1/S2) surfaces.

HCP
HC PHOTONICS CORP.

D. Optical Testing

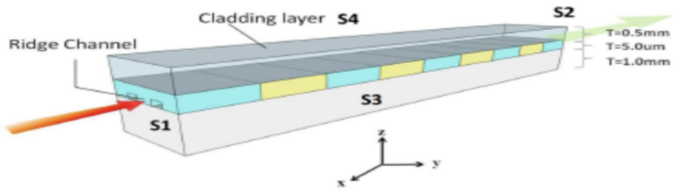


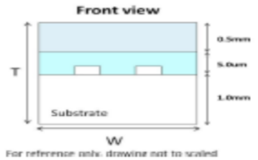
9:17 4G

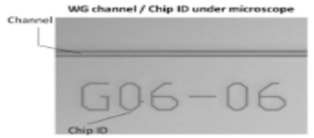
following items—

1. Please refer to the attached test report and confirm if the light was coupled at the right position
2. For type-2, the optic axis goes like: 1560nm(o wave)+1560nm(e wave) à 780nm(o wave)

Did your optic axis correspond to it?





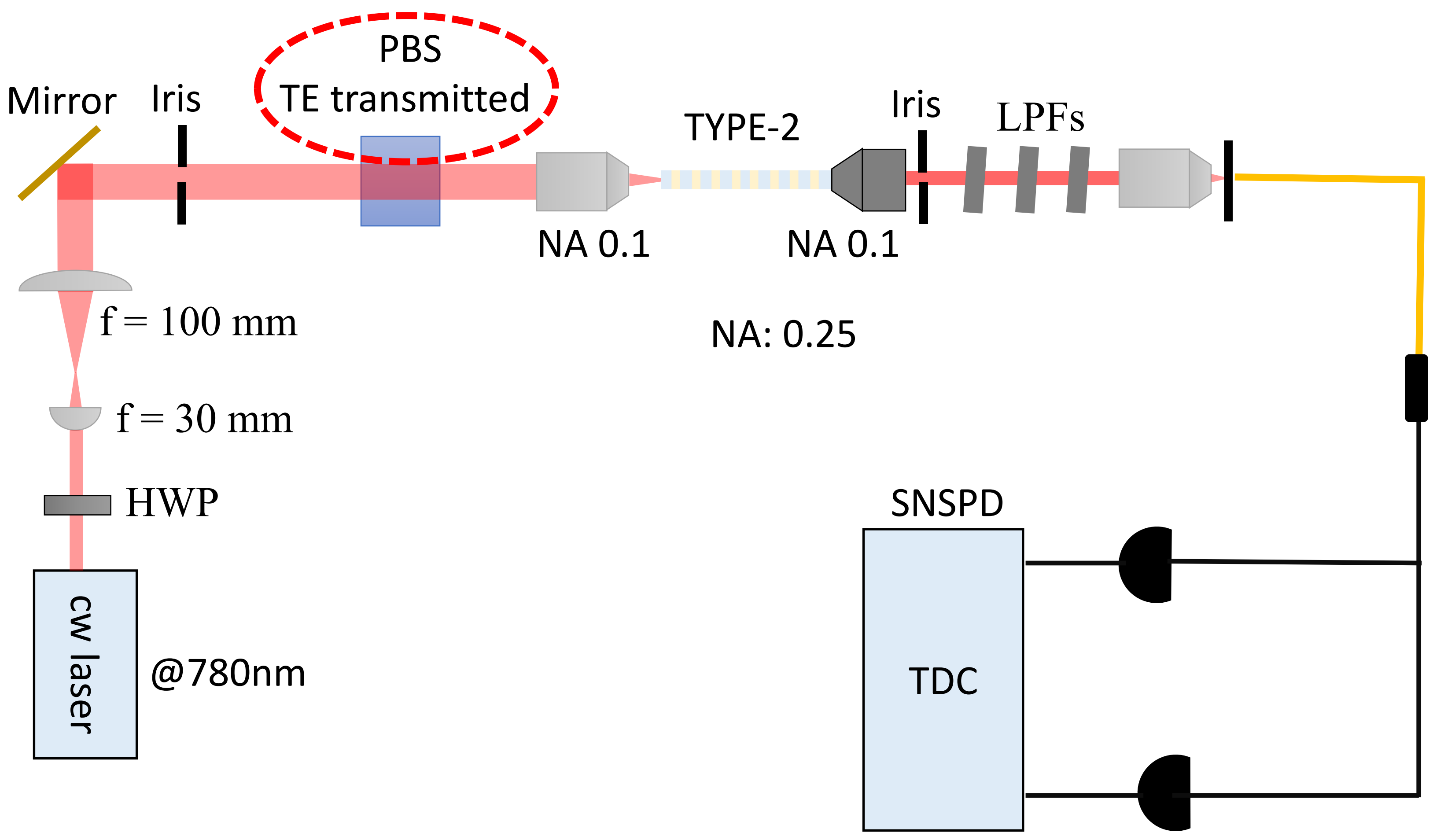


3. The PMT(phase matching temperature), by the test report, is ~31degC. Have you scanned the temperature for optimal output?

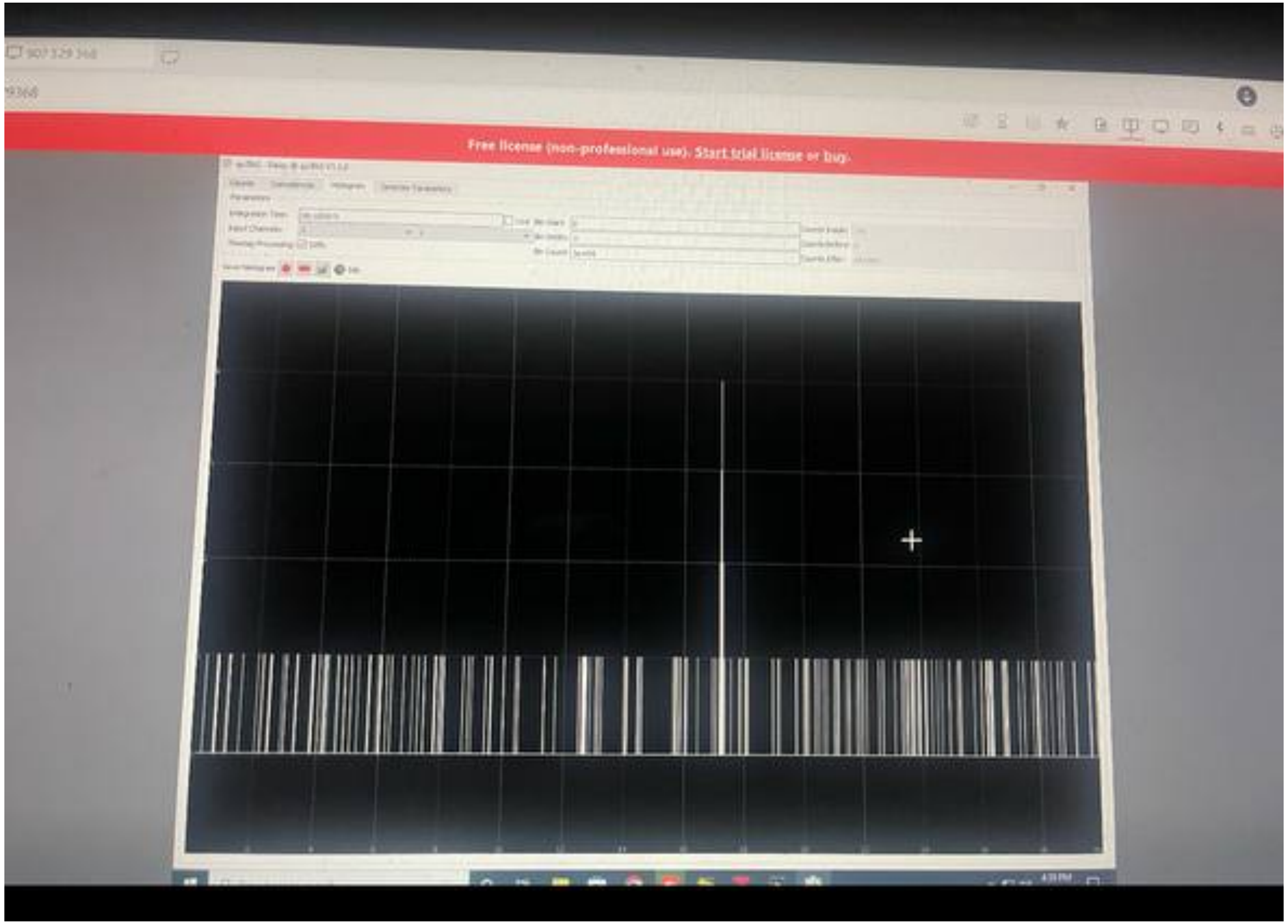
	Chip ID	Length (mm)	Wavelength (nm)	Intrinsic efficiency (%/W)	Phase match temperature (°C)	Result
Specification		10	SPDC 780 => 1560+ 1560	~1.8	45+/-20	
Measured data	AP-Y190102-11-G07-01-06	10.3	SPDC 780 => 1560+ 1560	~2.2	~31	PASS

Reply to All

Mail Calendar Feed Apps

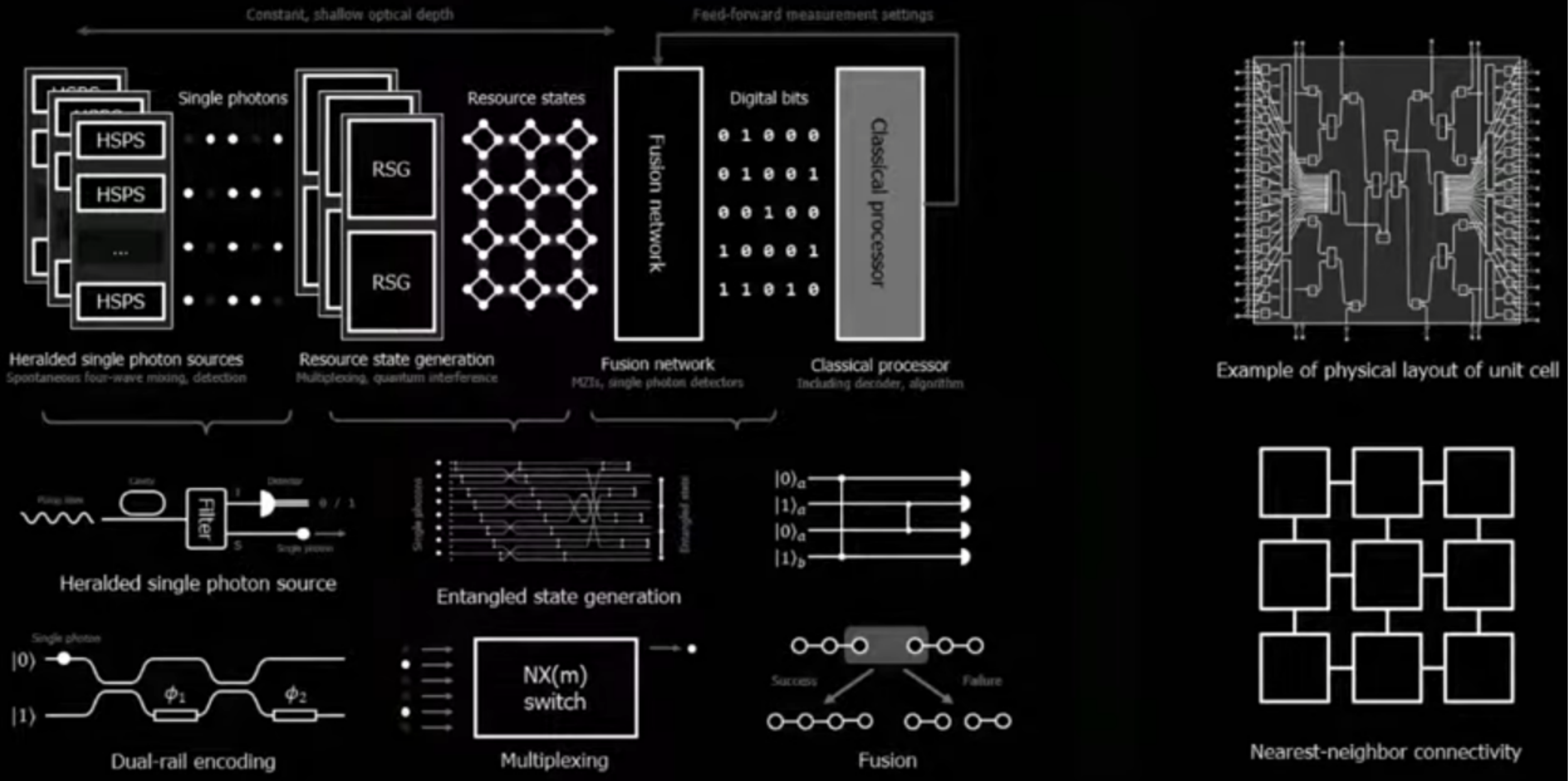

PBS
TE transmitted
Mirror
Iris
TYPE-2
Iris
LPFs
NA 0.1
NA 0.1
f = 100 mm
NA: 0.25
f = 30 mm
HWP
SNSPD
cw laser
@780nm
TDC

Coincidence for type 2



State of the art and challenges

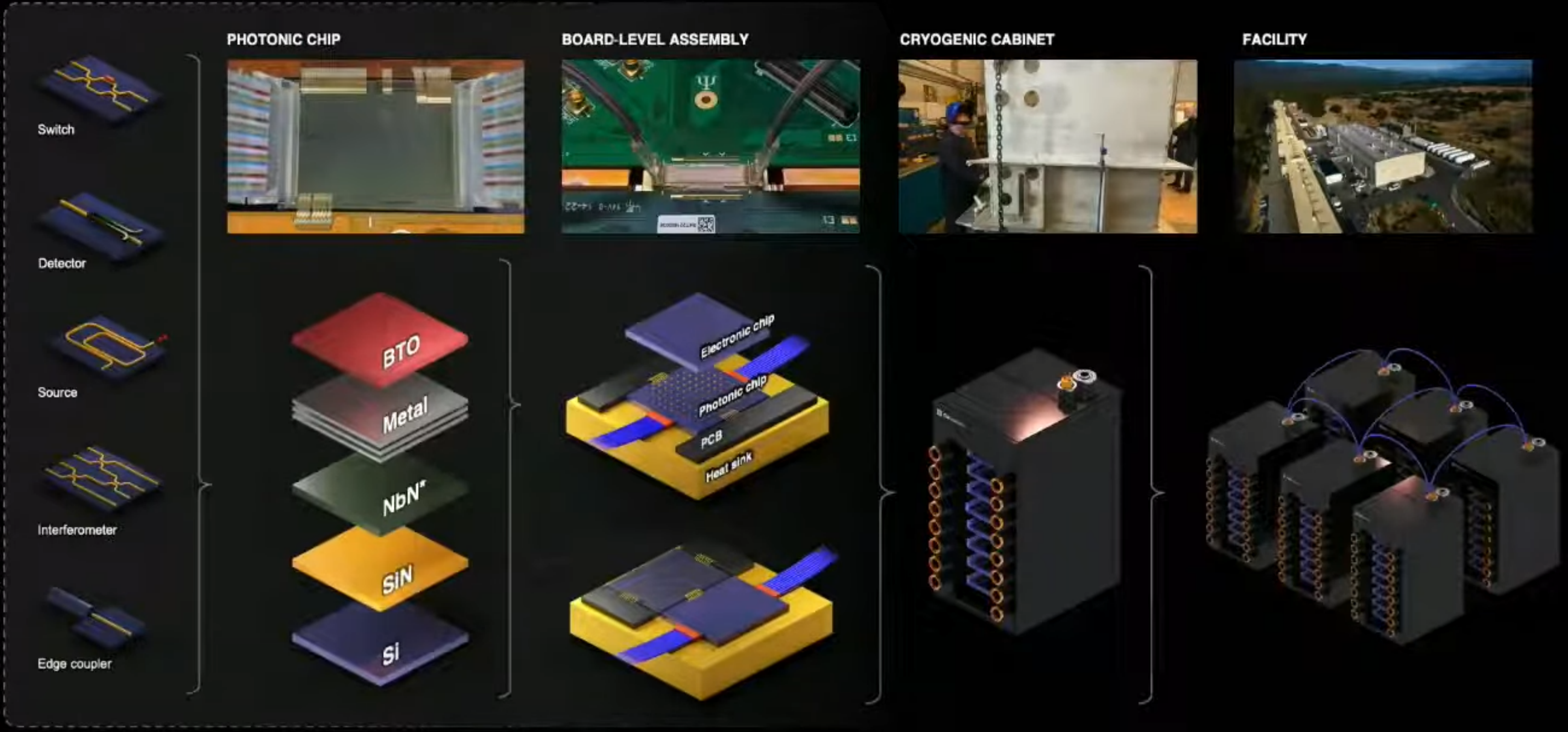
PsiQuantum



PsiQuantum

arXiv: 2109.13760, 2103.08612, 2101.09310, 1709.06218...

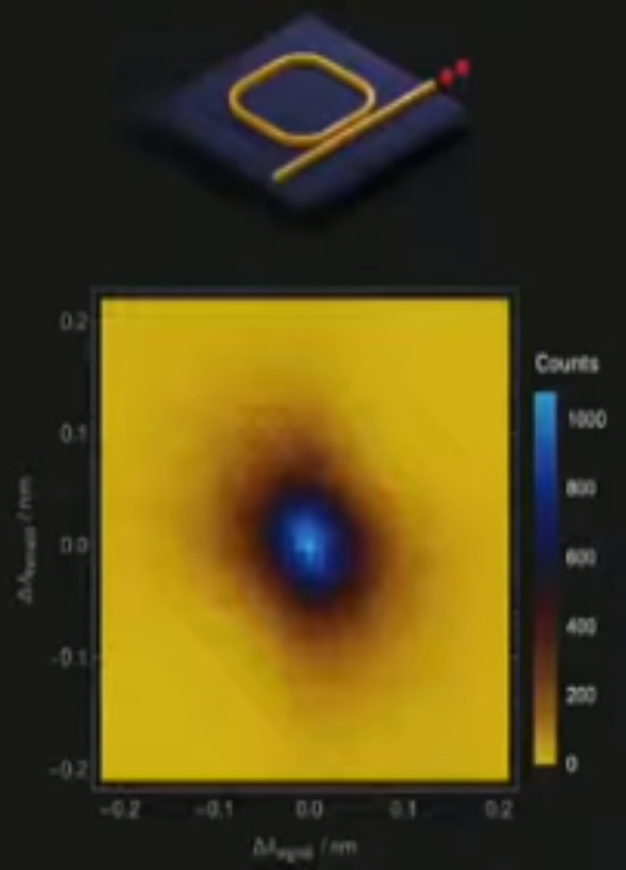
Map of a photonic quantum computer



SCOPE OF EXISTING HARDWARE →

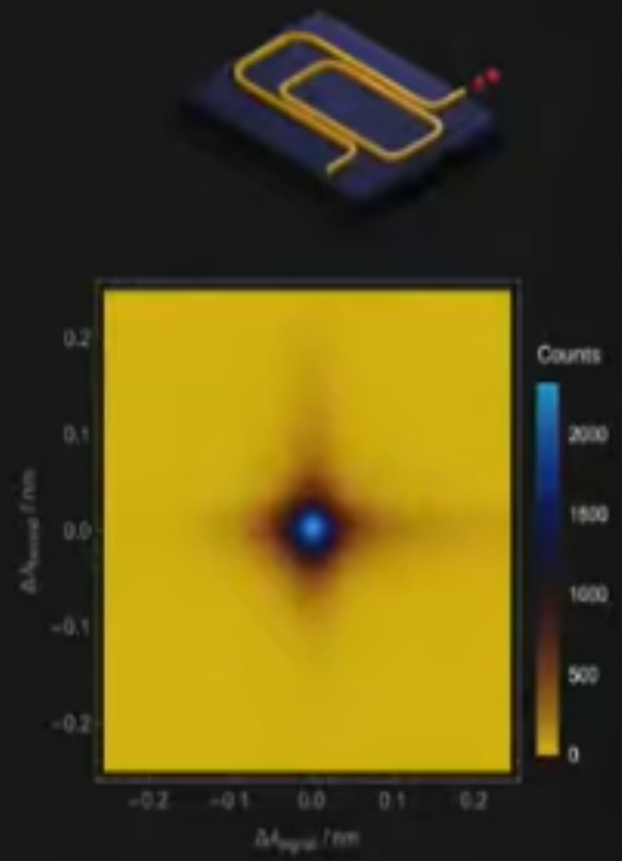
Single photon generation

SCOPE OF EXISTING HARDWARE →



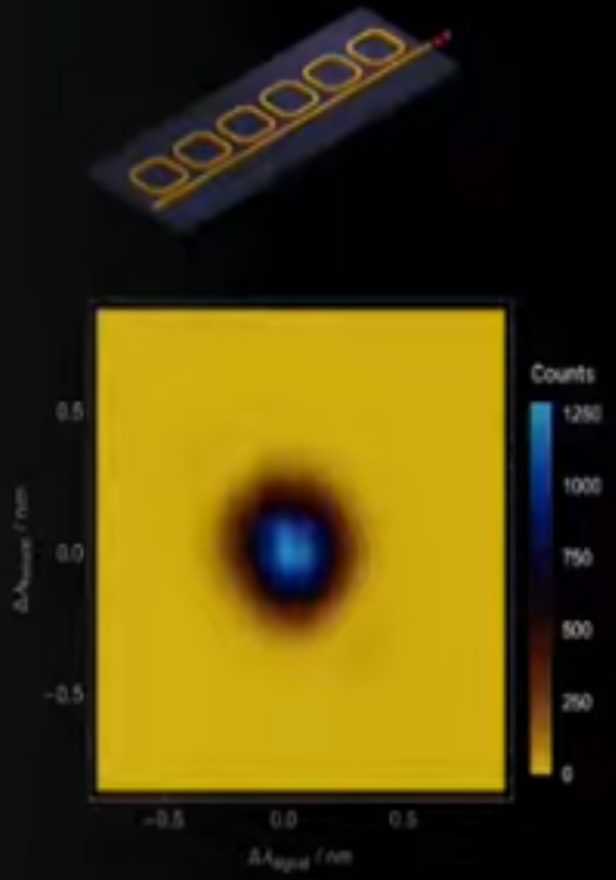
~90% purity

EXPERIMENT



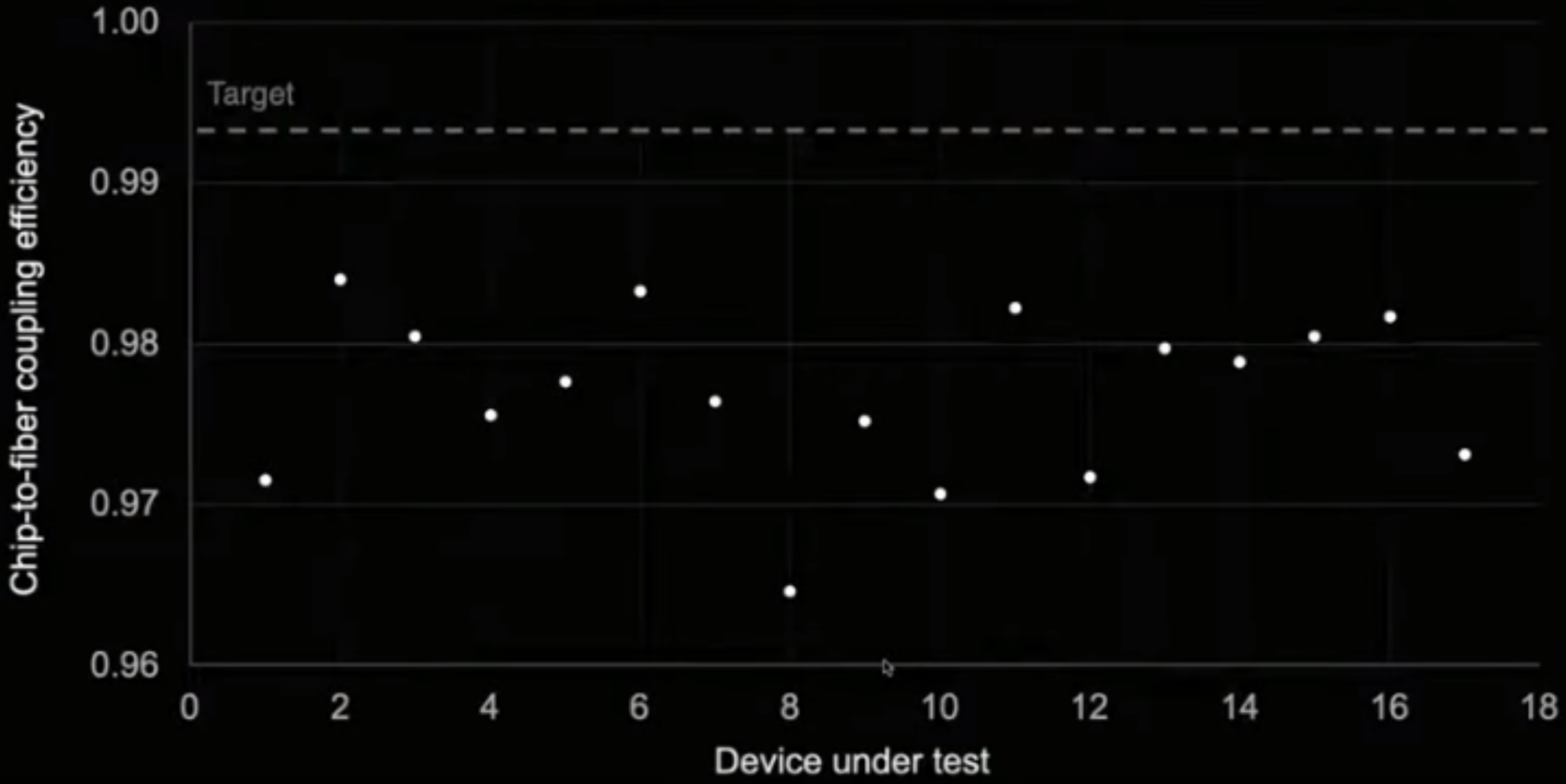
~99.5% purity

EXPERIMENT

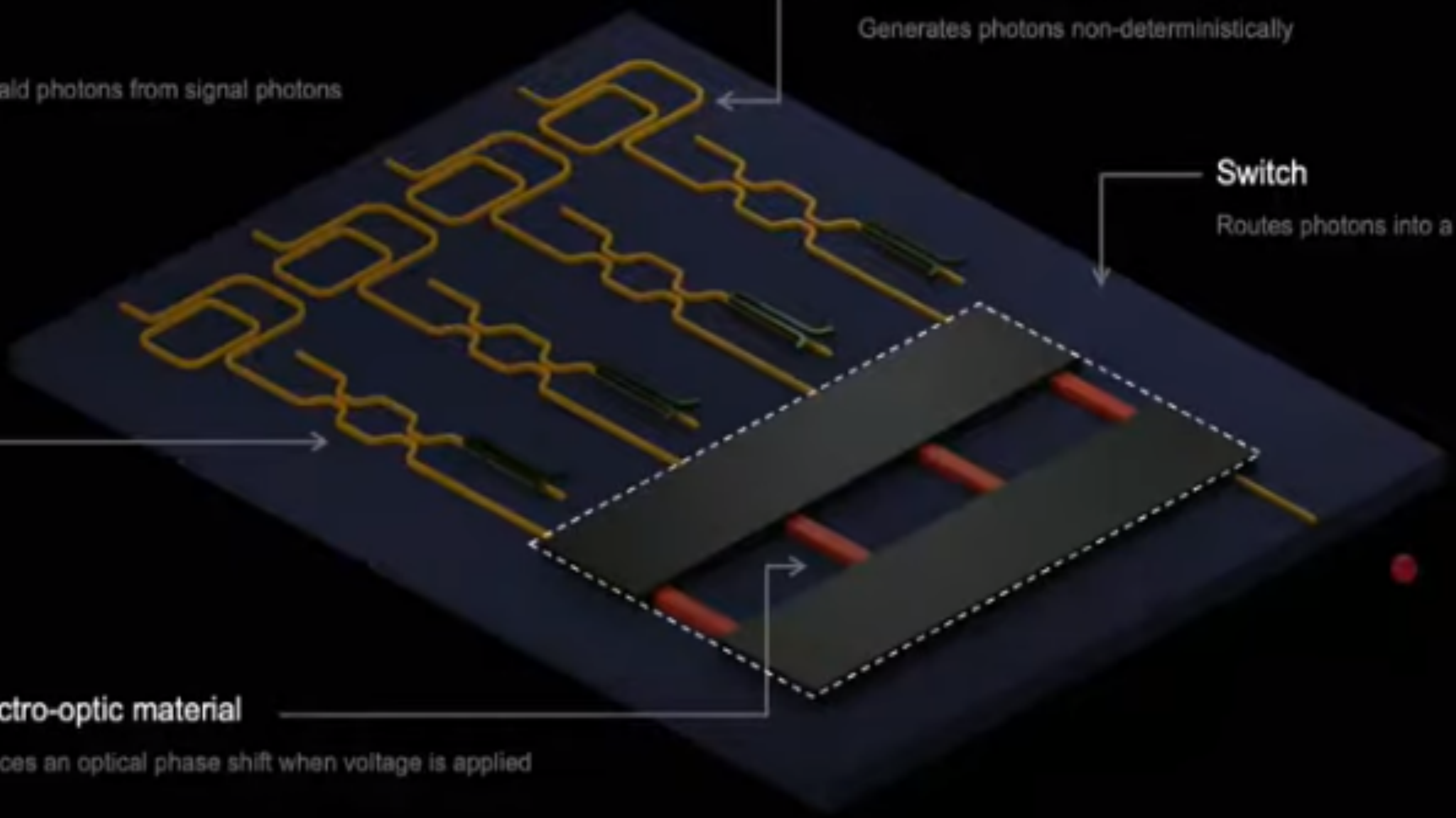


~99.9% purity

SIMULATION

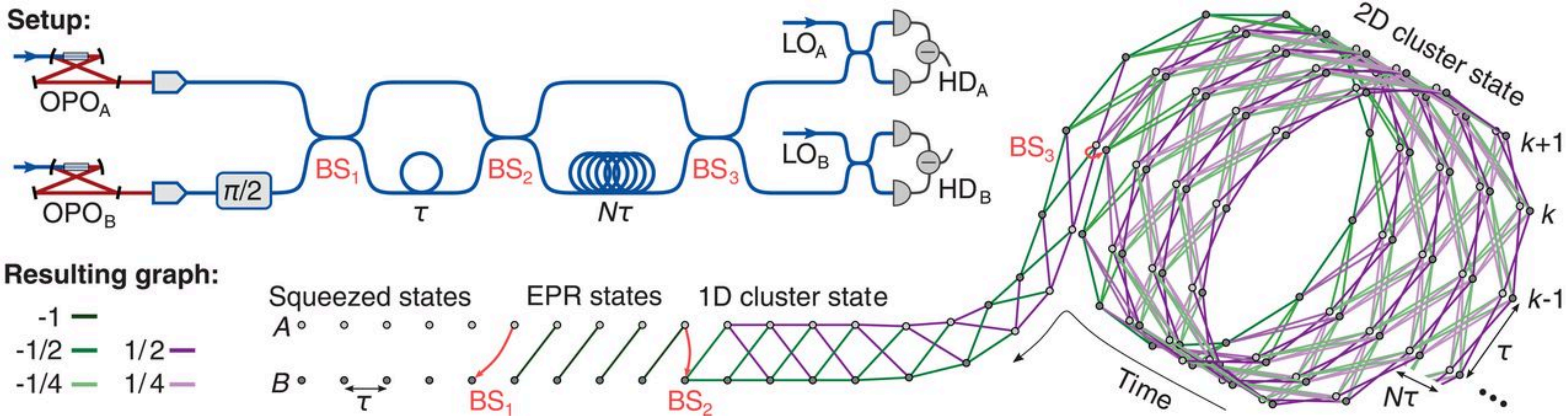

1.00
0.99
0.98
0.97
0.96
Target
Chip-to-fiber coupling efficiency
0
2
4
6
8
10
12
14
16
18
Device under test

Optical switching

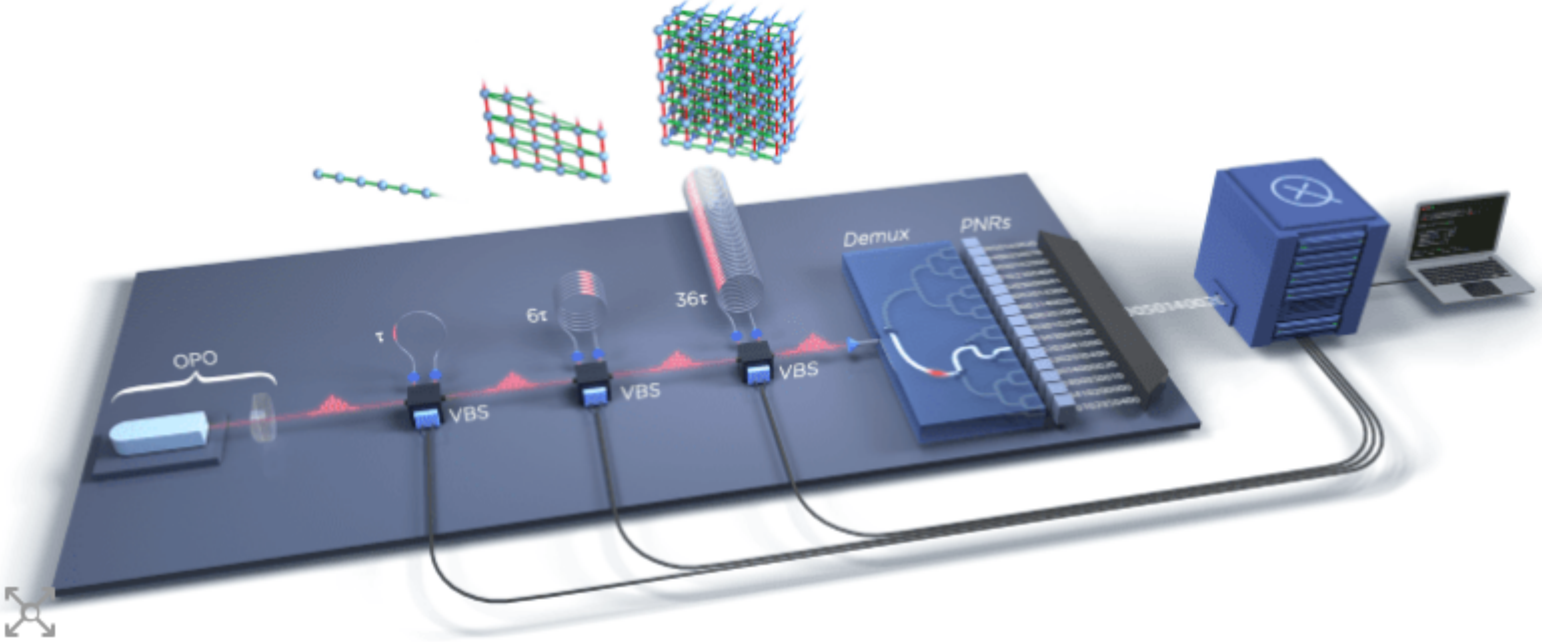


XANADU

Deterministic generation of cluster state



Borealis



Thanks for your attention!