

Generating and teleporting entanglement for quantum networks

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Motivation

- ▶ Bright source of entanglement

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- ▶ Training in quantum technologies in Slovenia

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- ▶ Bright source of entanglement
- ▶ Training in quantum technologies in Slovenia
- ▶ Quantum Network for Slovenia
- ▶ Testbed for industrialized version

Theory

1. SPDC
2. Entanglement swapping

- Spontaneous Parametric Downconversion

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$$\omega_p = \omega_s + \omega_i$$

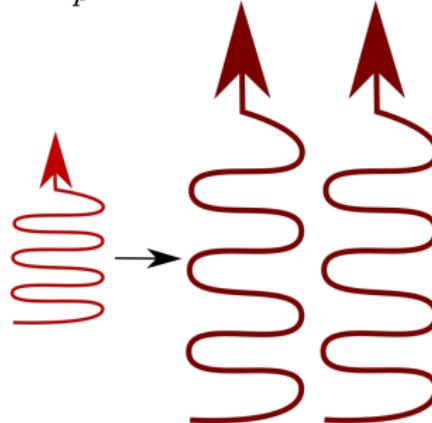


Illustration of SPDC

Theory SPDC

- #### ► Spontaneous Parametric Downconversion

$$\omega_p = \omega_s + \omega_i$$

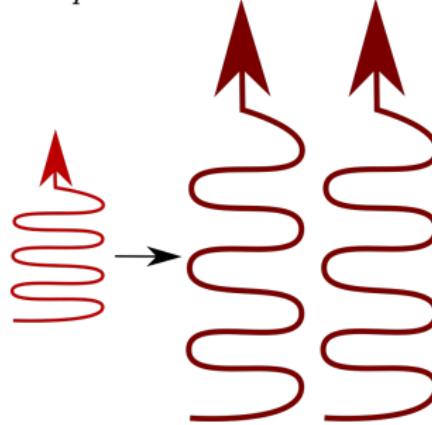


Illustration of SPDC

- ### ► Degenerate

Theory SPDC

- #### ► Spontaneous Parametric Downconversion

$$\omega_p = \omega_s + \omega_i$$

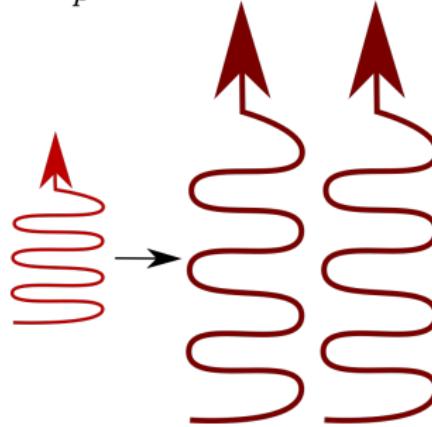


Illustration of SPDC

- Degenerate $\omega_i = \omega_s$

Theory

SPDC

- #### ► Spontaneous Parametric Downconversion

$$\omega_p = \omega_s + \omega_i$$

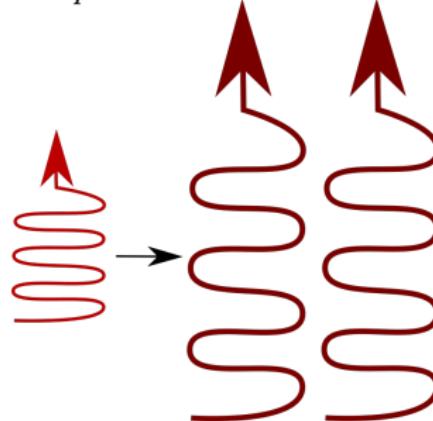


Illustration of SPDC

- Degenerate $\omega_i = \omega_s$
 - Non-degenerate

Theory

SPDC

- #### ► Spontaneous Parametric Downconversion

$$\omega_p = \omega_s + \omega_i$$

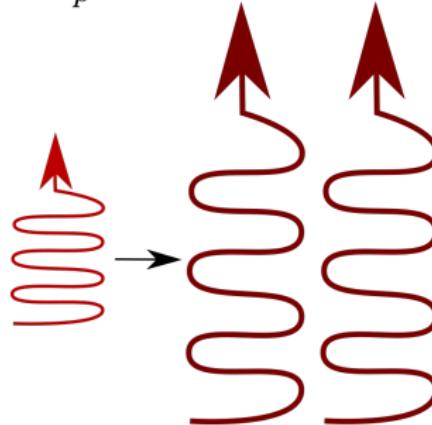


Illustration of SPDC

- Degenerate $\omega_i = \omega_s$
 - Non-degenerate $\omega_i \neq \omega_s$

Theory

State of the Art

Comparison of different sources

Who When	[1] 2022	[2] 2010	[3] 2007	[4] 2006	[5] 2012
Type	0	II	II	II	0
Brightness/ $\frac{\text{pairs}}{\text{sm} \text{W} \text{nm}}$	$2,5 \times 10^6$	$87,5 \times 10^3$	273×10^3	5×10^3	278×10^3
Bandwidth/nm	106	0,3	0,3	1	2,3

SPDC

Phase Matching, Quasi Phase Matching, Bandwidth

- #### ► Phase Matching, Quasi Phase Matching

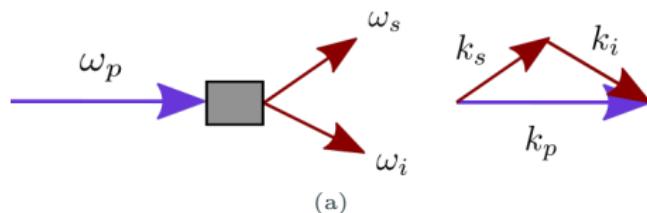


Illustration of a) Phase Matching $k_p = k_i + k_s$ and

SPDC

Phase Matching, Quasi Phase Matching, Bandwidth

- #### ► Phase Matching, Quasi Phase Matching

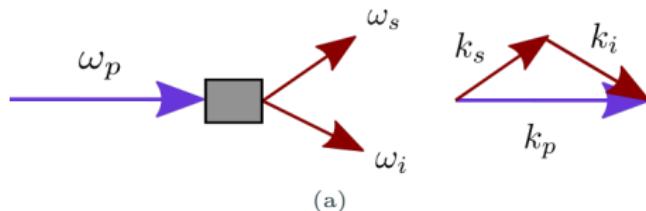
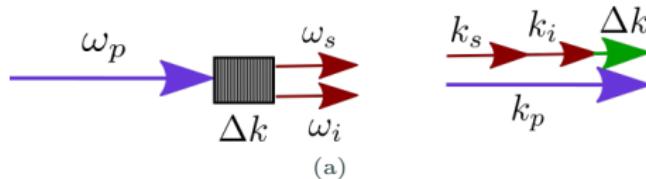


Illustration of a) Phase Matching $k_p = k_i + k_s$ and

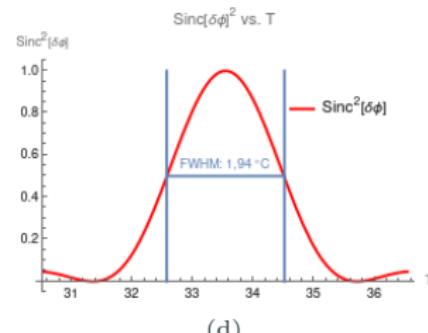
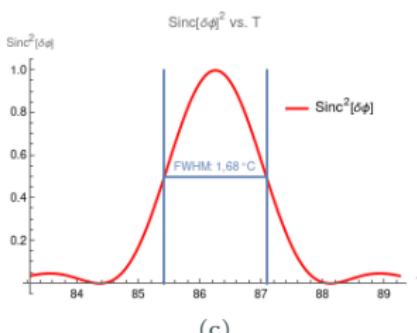
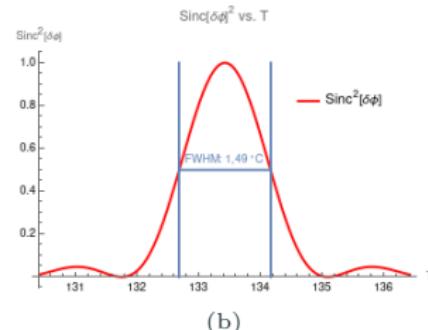
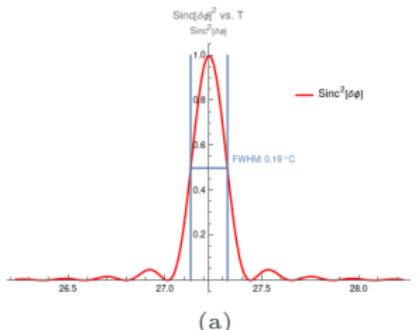


b) Quasi Phase Matching $k_p - k_i - k_s - \Delta k = 0$.

Theory

Phase Matching Temperature

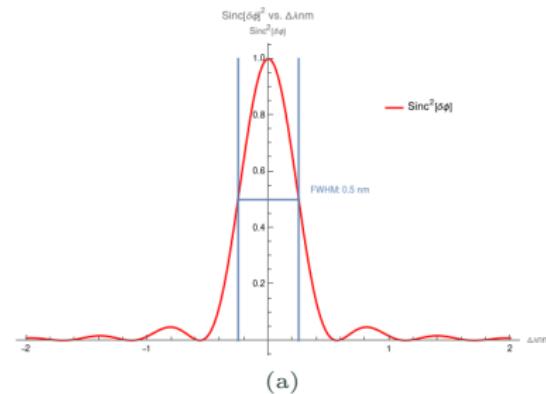
Phase Matching Temperature calculations for a) Type-2 crystal of 9,12 μm polling period, b) Type-0, 19,25 μm , c) Type-0, 19,45 μm , d), Type-0 19,65 μm



Type-II vs Type-0

Bandwidth

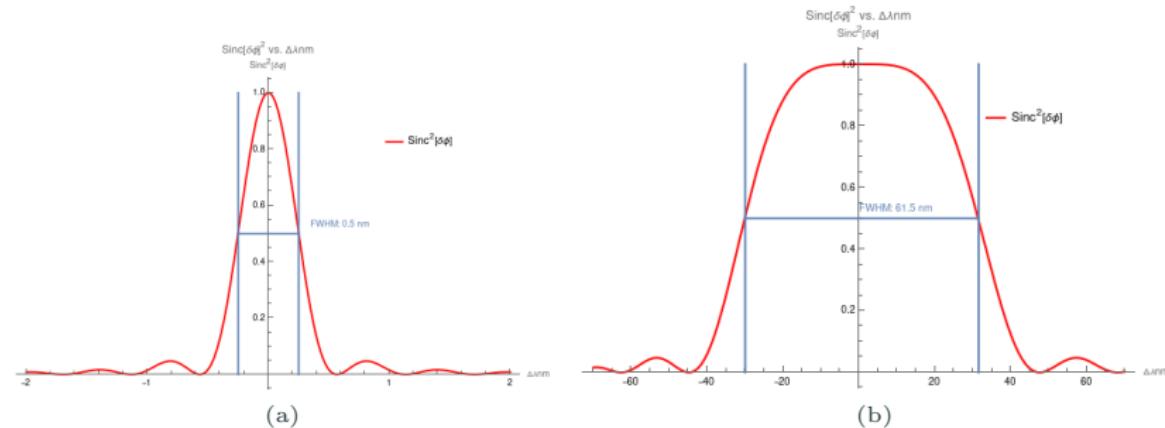
Wavelength bandwidth of a) Type-2 crystal with a polling period of 9,12 μm
 b) Type-0 crystals with polling periods of 19,25 μm



Type-II vs Type-0

Bandwidth

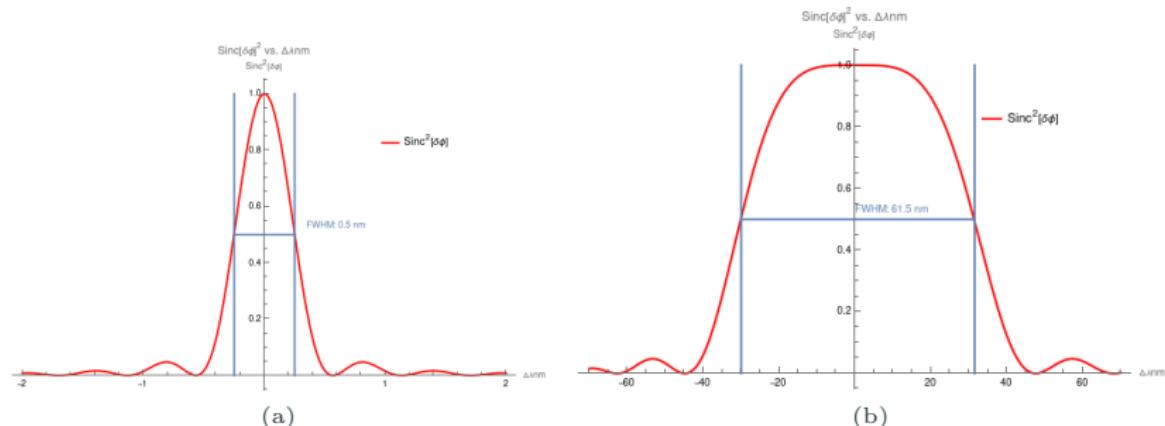
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Type-II vs Type-0

Bandwidth

Wavelength bandwidth of a) Type-2 crystal with a polling period of 9,12 μm
 b) Type-0 crystals with polling periods of 19,25 μm



$$|\Psi_p\rangle = \frac{1}{\sqrt{2}} (\sin(\alpha) a_H^\dagger + \cos(\alpha) a_V^\dagger) |0\rangle$$

$$|\Psi_{\text{Type-2}}\rangle = \frac{1}{\sqrt{2}} (\sin(\alpha) a_H^\dagger(\omega_s) a_V^\dagger(\omega_i) +$$

$$\cos(\alpha) a_V^\dagger(\omega_i) a_H^\dagger(\omega_s)) |0\rangle$$

(1)

$$|\Psi_{\text{Type-0}}\rangle = \frac{1}{\sqrt{2}} (\sin(\alpha) a_H^\dagger(\omega_s) a_H^\dagger(\omega_i) +$$

$$\cos(\alpha) a_V^\dagger(\omega_i) a_V^\dagger(\omega_s)) |0\rangle$$

SPDC

Type-2 vs Type-0

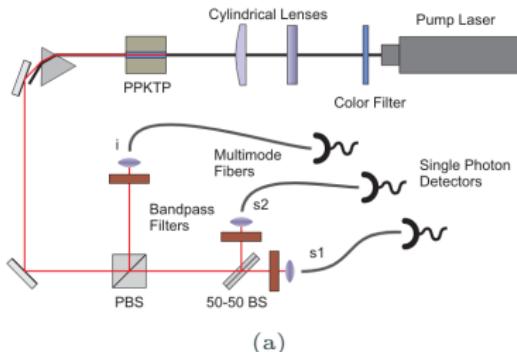
Brightness comparison

$Hz/mW/nm$

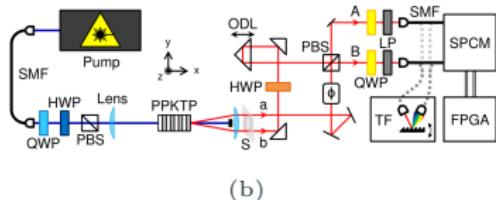
FMF		IJS
Type-II	Type-0	Type-II
$7,8 \times 10^6$	$2,6 \times 10^7$	$0,05 \times 10^6$
Bandwidth/nm		
0,68	0,68	0,68

Different Designs

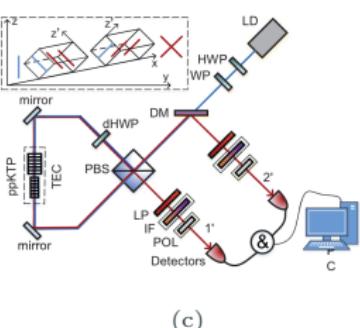
Different design ideas from other groups. a) [6], b) [7], c) [8], d) [9]



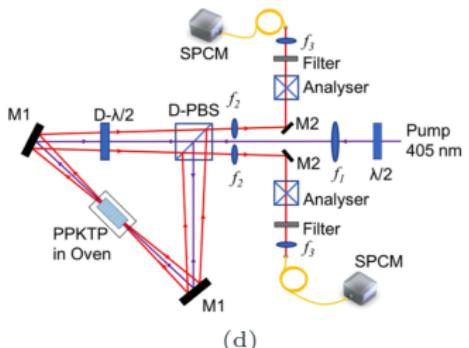
(a)



(b)



(c)



(d)

Entanglement swapping

- ▶ No specific form required - arbitrary states can be teleported
 - 1. Bell State Measurements
 - 2. Will try to use Quantum Memory from IJS group
- ▶ FMF/IJS

Present state

Parameters

- ▶ Focusing parameters [10]

$$\xi = \frac{L}{kw^2} \quad (2)$$

- ▶ Heraldng

Present state

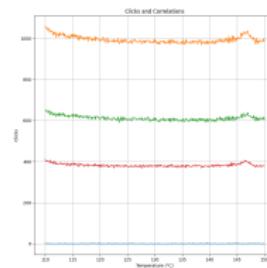
Phase Matching Temperature

Temperature scans of Type-0 crystals with different polling periods, a) misaligned 19,25 μm , b) 19,25 μm , c) 19,45 μm , d) 19,65 μm

Present state

Phase Matching Temperature

Temperature scans of Type-0 crystals with different polling periods, a) misaligned 19,25 μm , b) 19,25 μm , c) 19,45 μm , d) 19,65 μm

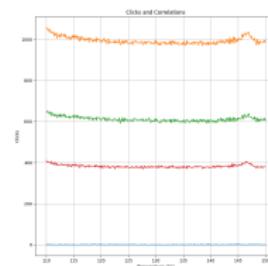


(a)

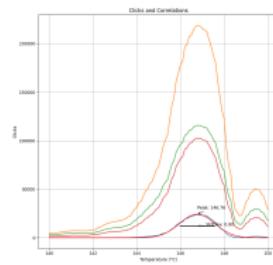
Present state

Phase Matching Temperature

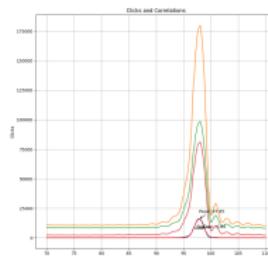
Temperature scans of Type-0 crystals with different polling periods, a) misaligned 19,25 μm , b) 19,25 μm , c) 19,45 μm , d) 19,65 μm



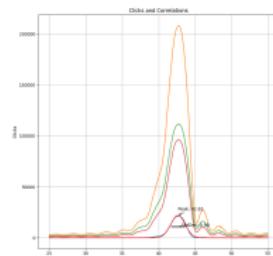
(a)



(b)



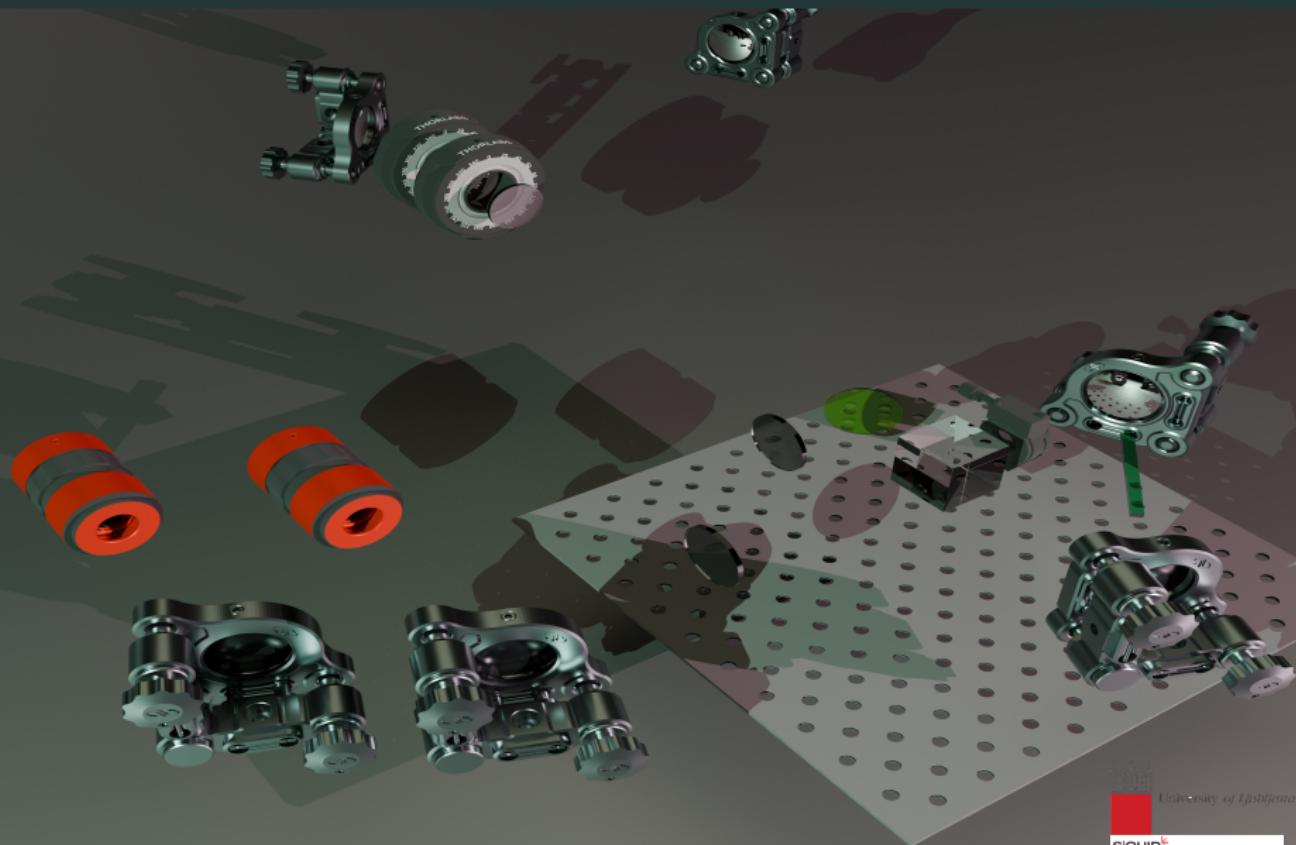
(c)



(d)

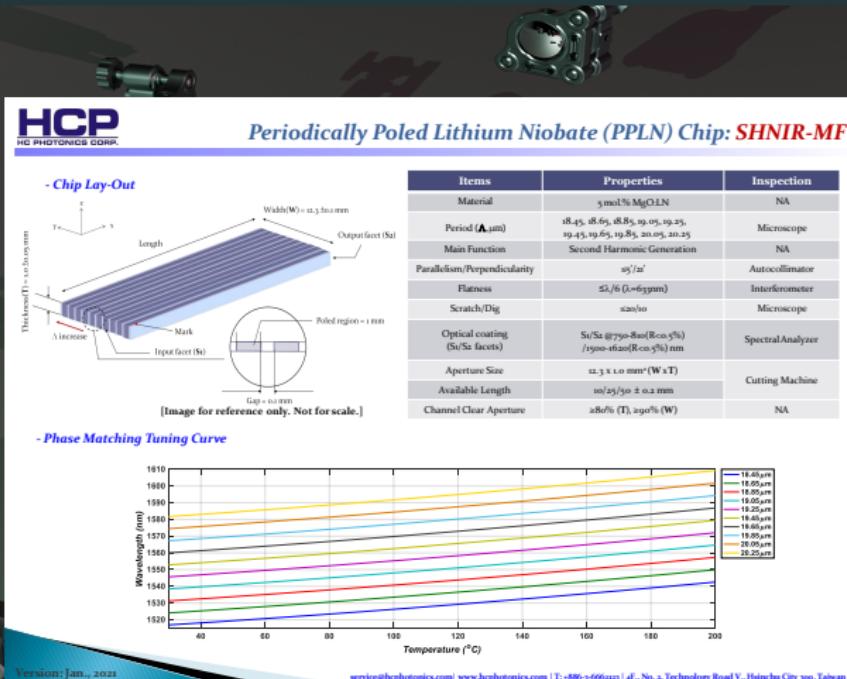
Present state

Building a Sagnac Interferometer



Present state

Building a Sagnac Interferometer



Specifications from the crystal manufacturer.

Outlook

- ▶ SiQUID
- ▶ Entanglement swapping between FMF and IJS
- ▶ Building quantum internet
- ▶ Free space link to reactor

Thank you

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