Title: A Polarization Entangled Photon Source Based on a Modified Sagnac Interferometer

Date: Jun 04, 2007 04:40 PM

URL: http://pirsa.org/07060026

Abstract: A new source of polarization entangled photons is presented based on a bidirectionally pumped spontaneous parametric down-conversion crystal in the loop of a Sagnac interferometer. The source is pumped with a pulsed Ti:SA laser, allowing for high photon pair production rates and the potential for multi-photon experiments. Implementation, detection, and preliminary experimental results will be discussed.

A Source of Polarization Entangled Photon Pairs based on a Dual Sagnac Interferometer

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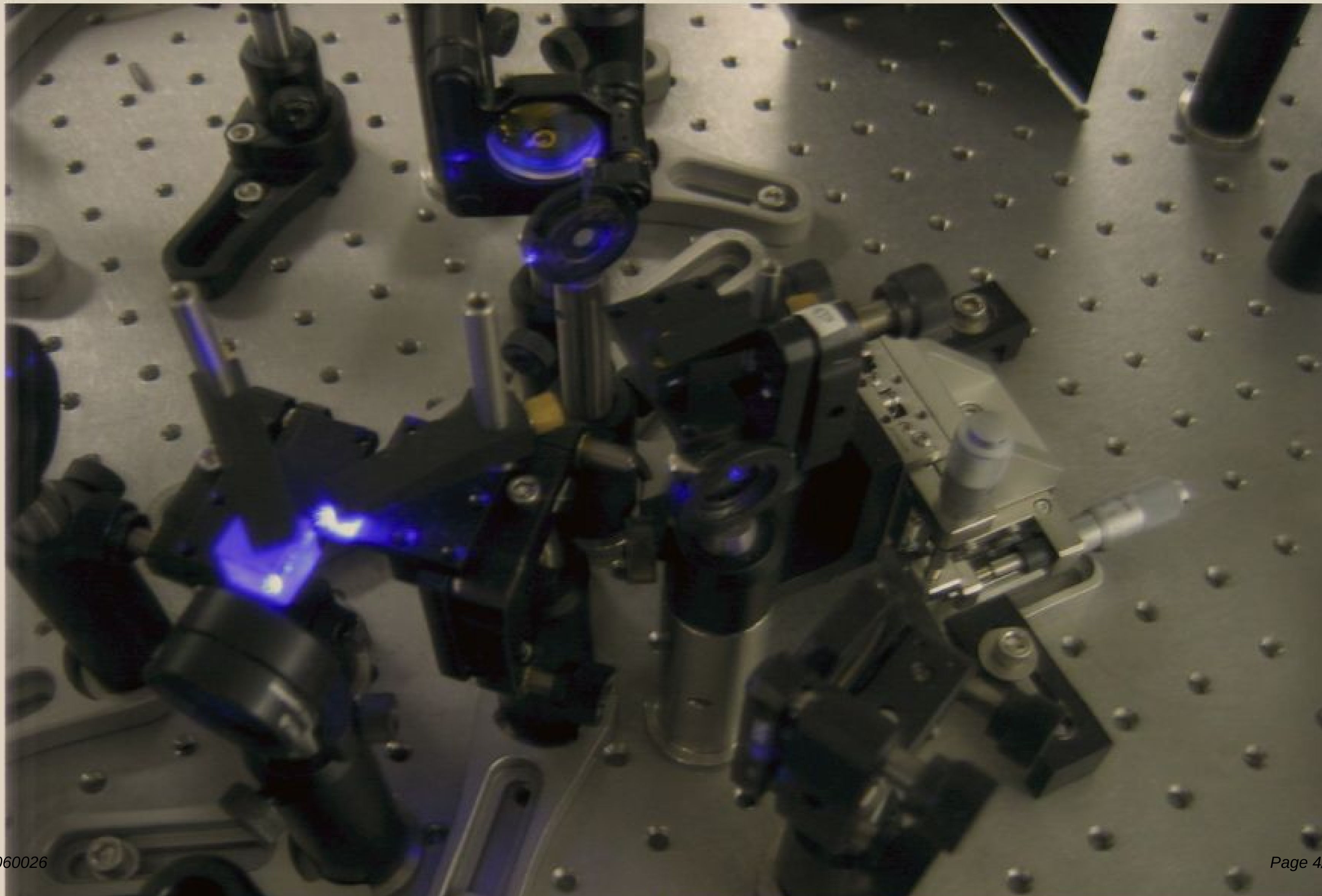
Canadian Quantum Information Students' Conference

Outline

1. Introduction
   - Entangled Photon Pairs
   - Spontaneous Parametric Down-Conversion
   - Sagnac Interferometers
2. Photon Pair Source
   - Design
   - Apparatus
   - Future Work

A Picture



A Resource for Quantum Information

- Entangled Photon Pairs are a building block for optical Quantum Information
- Typically in a Bell state, *e.g.* $|01\rangle + e^{i\phi}|10\rangle$
- Used in:
  - Quantum Key Distribution
  - Quantum Communication
  - Teleportation
  - EPR Tests
  - Cluster State Computing

Types of Entaglement

Several degrees of freedom are available to use as qubit states in photons:

- Polarization
- Time-bin
- Spacial Mode
- Photon Number
- Dual Rail

A quantum nonlinear effect

- Spontaneous parametric down conversion provides a source of photon pairs with good correlation in their creation times.
- Is about $10^{-10} \rightarrow 10^{-8}$ efficient

Let $a_j = a(\vec{k}_j, p_j)$, where $a\,|n\rangle = \sqrt{n}\,|n-1\rangle$

$$H \approx F_0 \sum_{p_s, p_i} \iint \mathrm{sinc}(\vec{k}_p - \vec{k}_s - \vec{k}_i) e^{i\omega_p t} (a_p a_s^\dagger a_i^\dagger + a_p^\dagger a_s a_i)\, \mathrm{d}^3 k_i\, \mathrm{d}^3 k_s$$

Phasematching

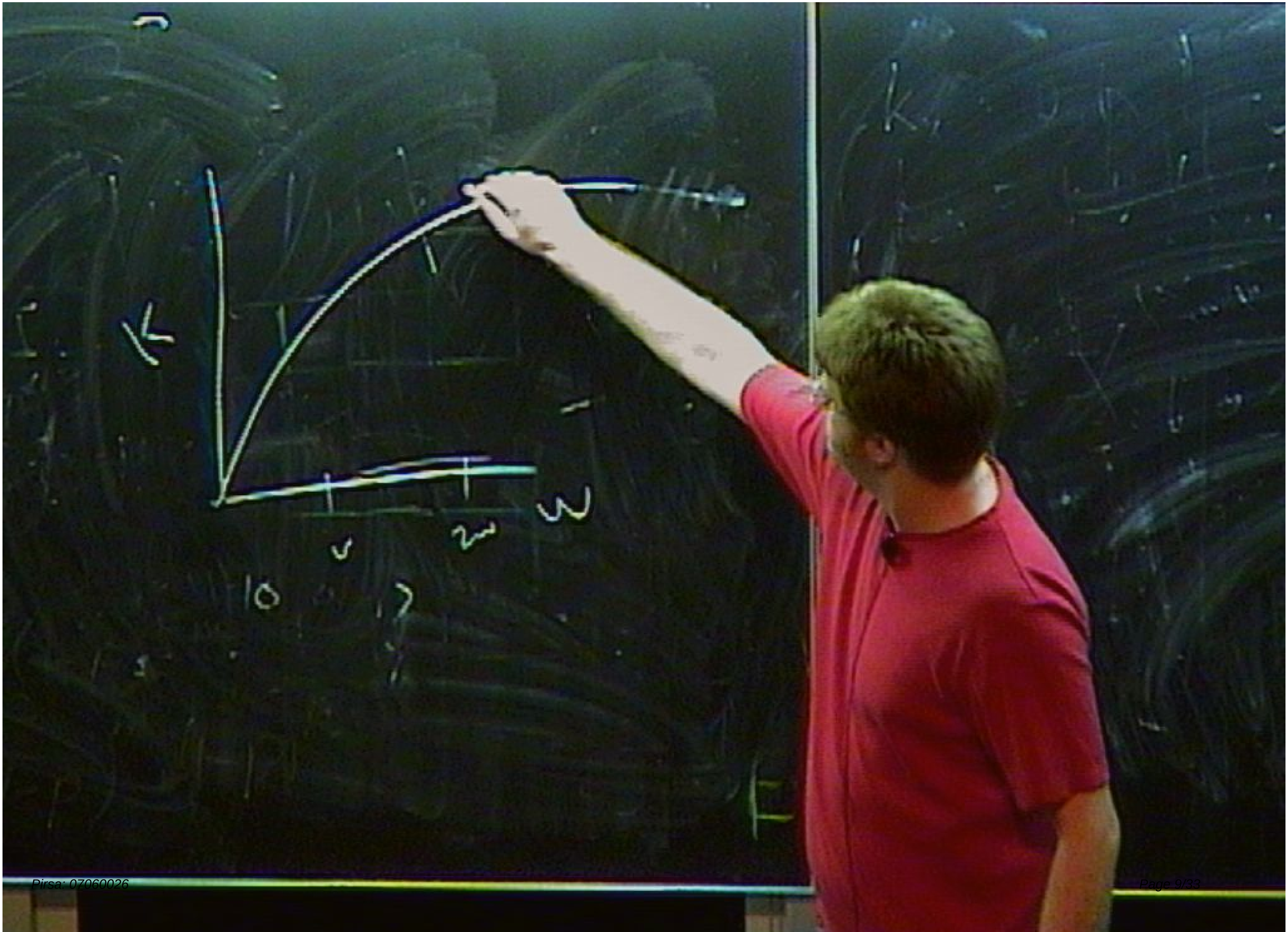
For SPDC to occur, energy and momentum must be conserved, *i.e.*

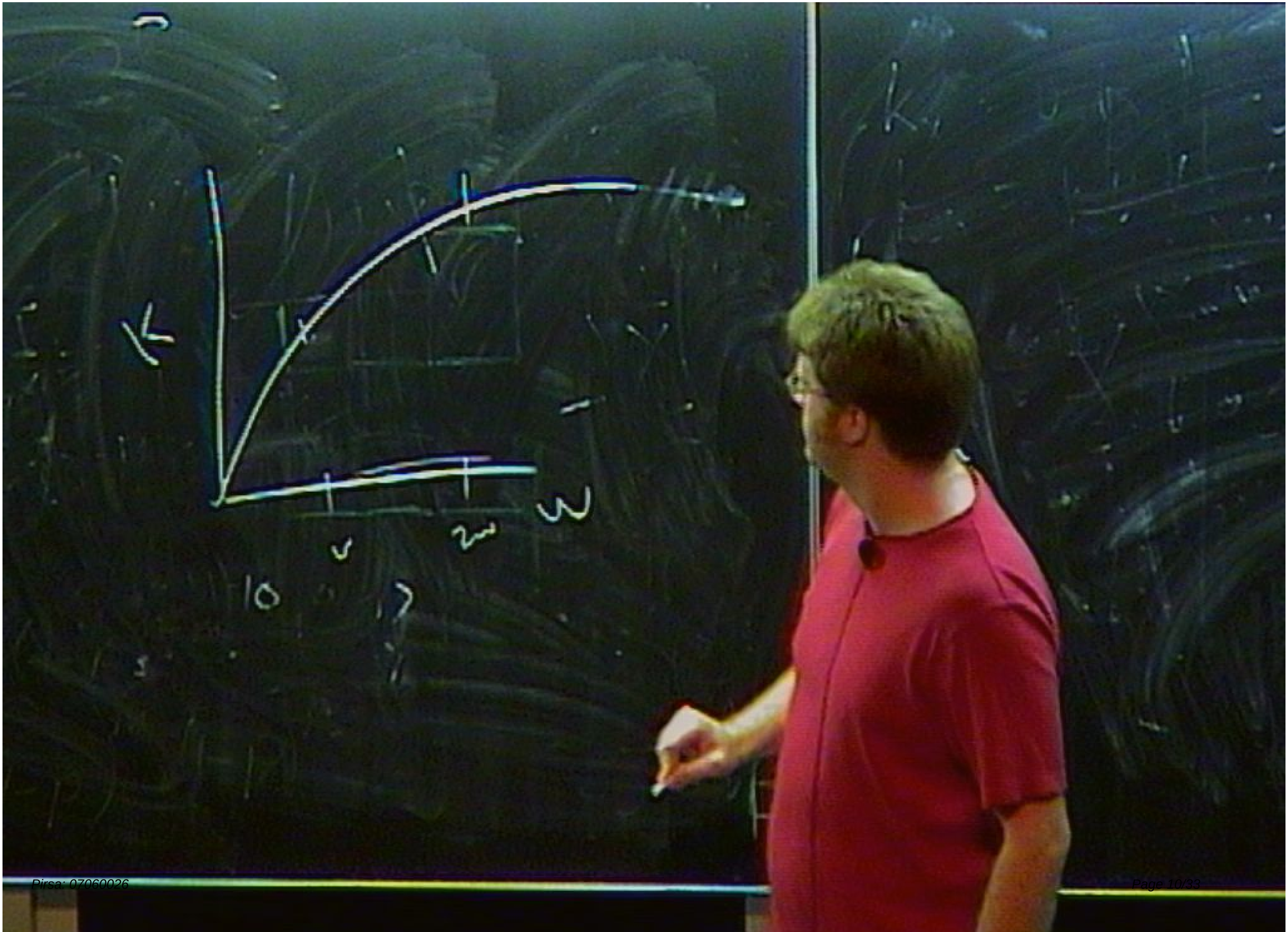
$$\hbar\omega_p = \hbar\omega_s + \hbar\omega_i$$
$$\hbar\vec{k}_p = \hbar\vec{k}_s + \hbar\vec{k}_i$$

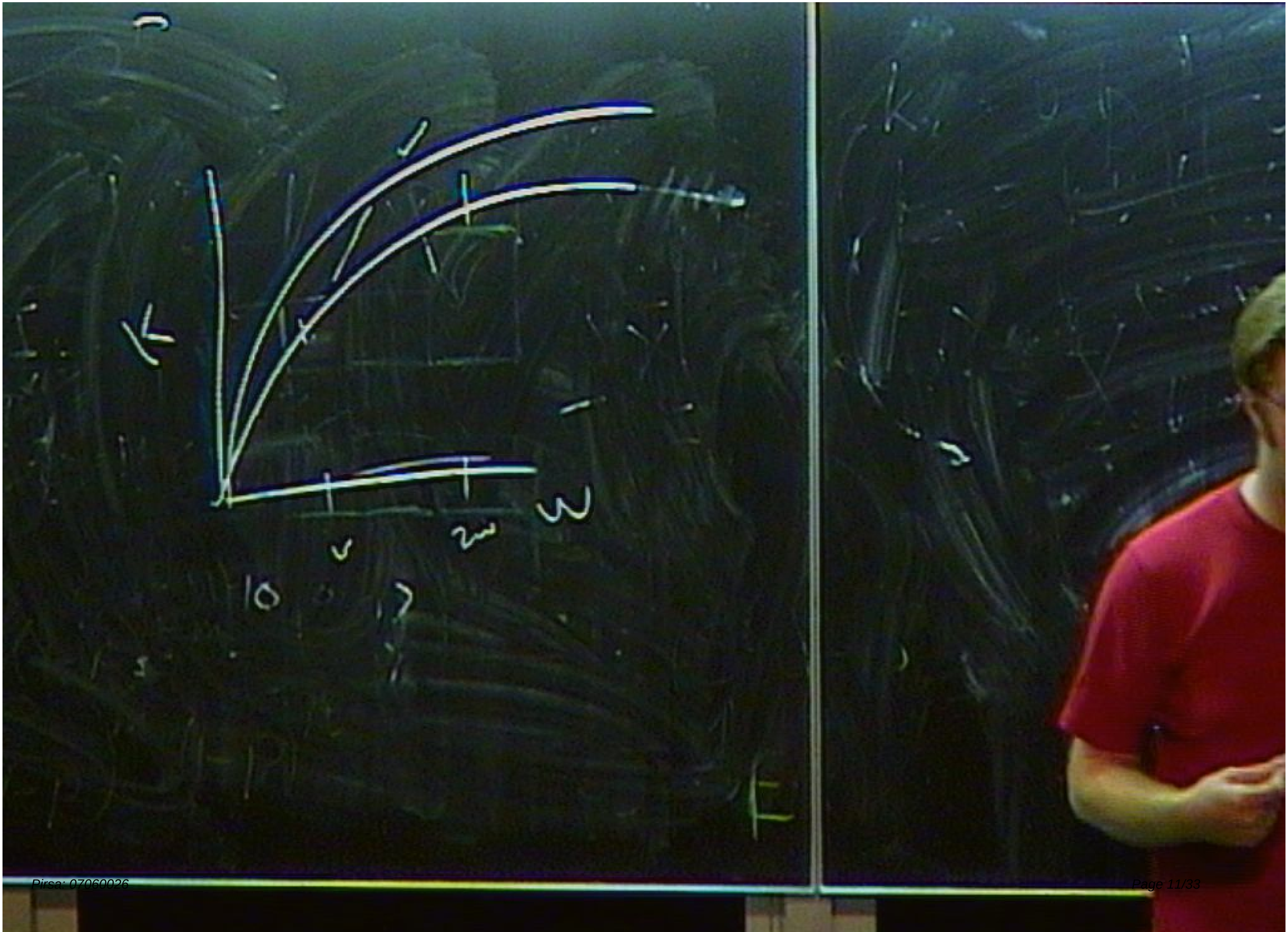
where $\vec{k} = \omega n(\omega, \vec{P})/c$ is the wavevector of the light. For almost all materials,

$$\frac{\partial k}{\partial \omega} \geqslant 0 \geqslant \frac{\partial^2 k}{\partial \omega^2}$$

Getting collinear phasematching is difficult at best....





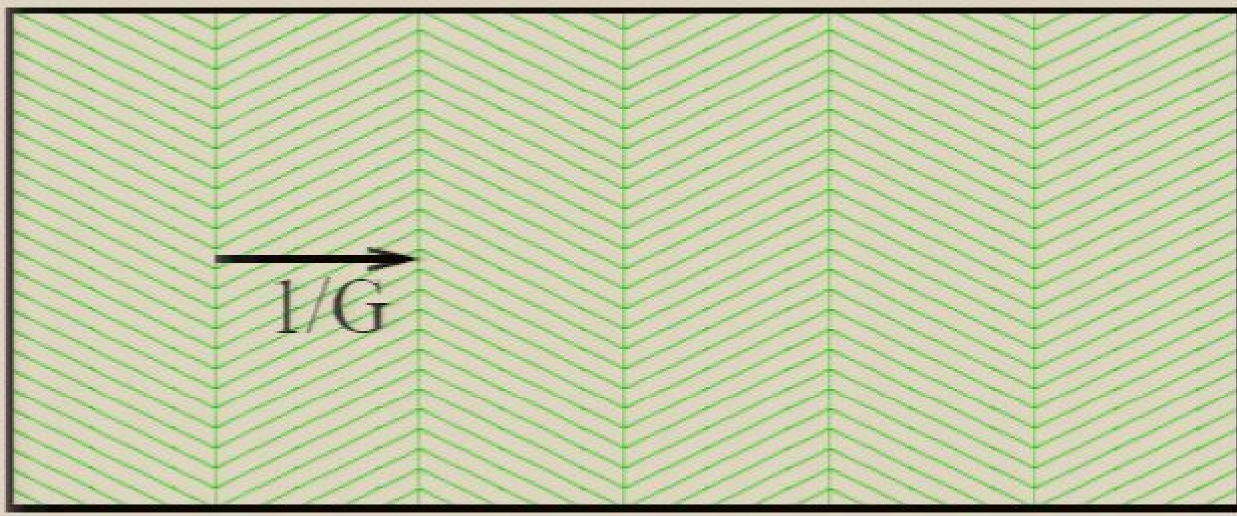

K
W
2w

Quasiphasematching

This can be solved using quasiphasematching,

$$\hbar k_p = \hbar k_s + \hbar k_i + \hbar G,$$

where G is a superlattice vector.



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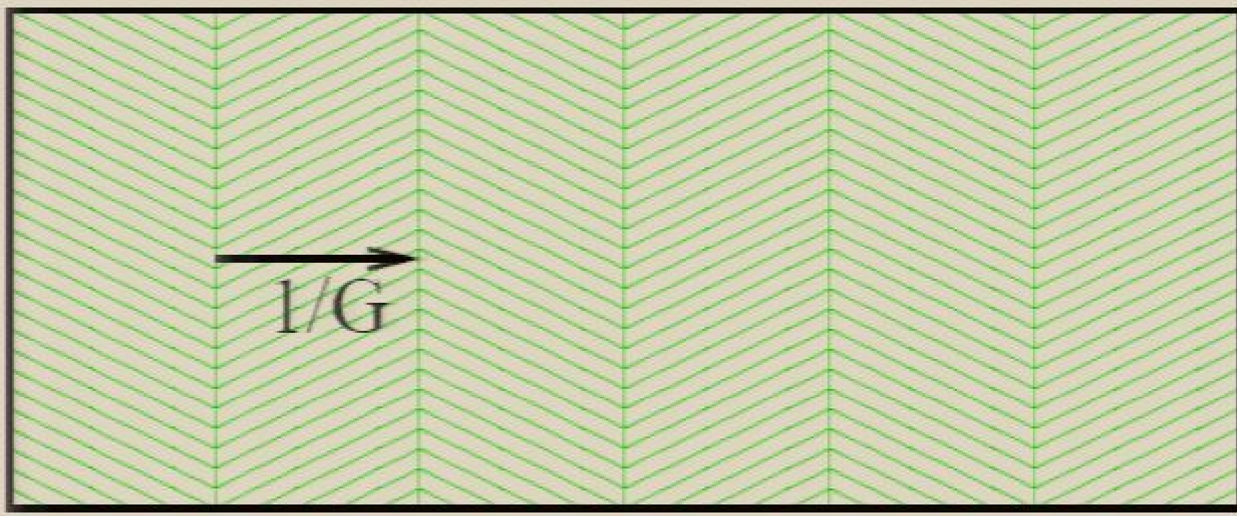
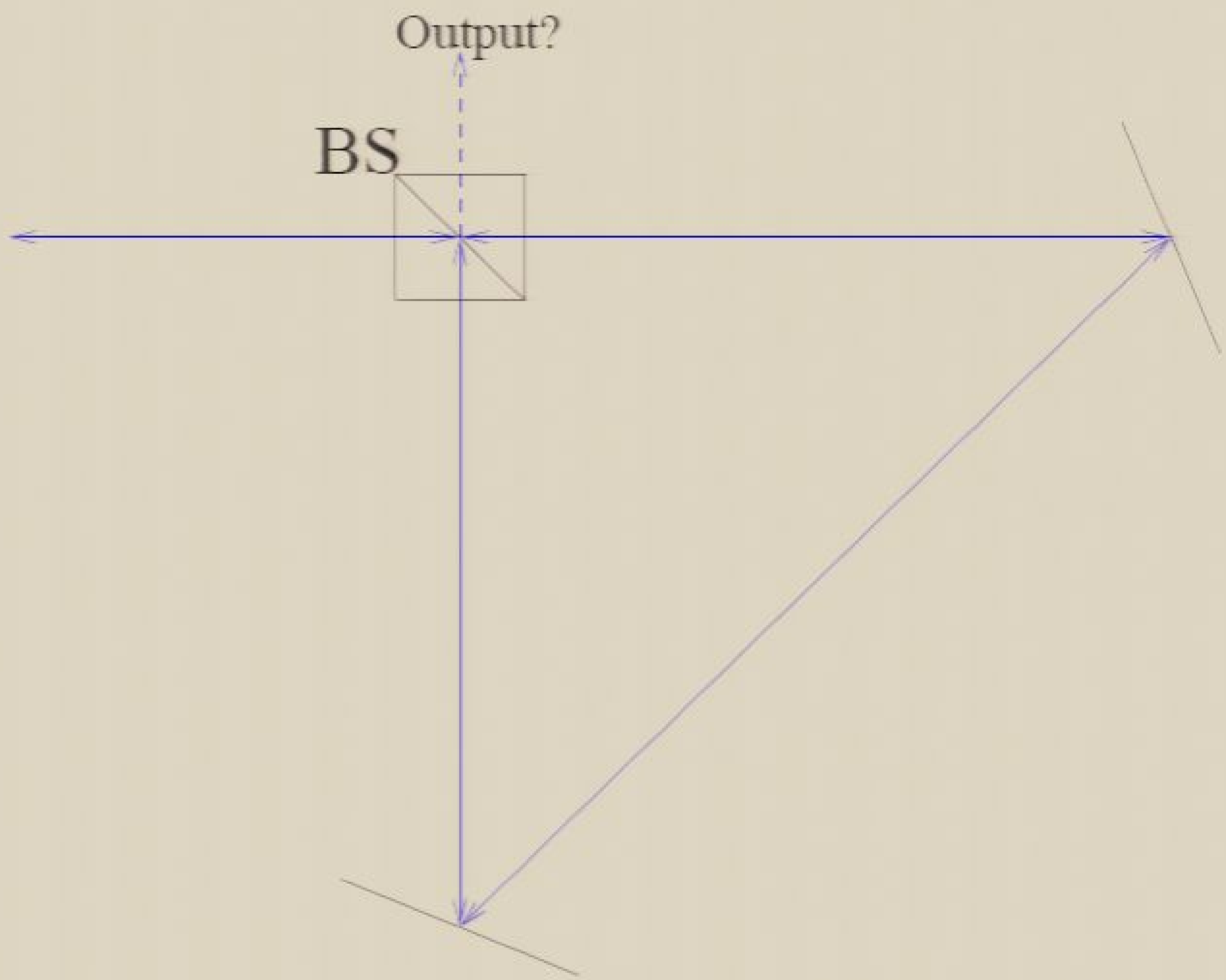


Classical Interferometry



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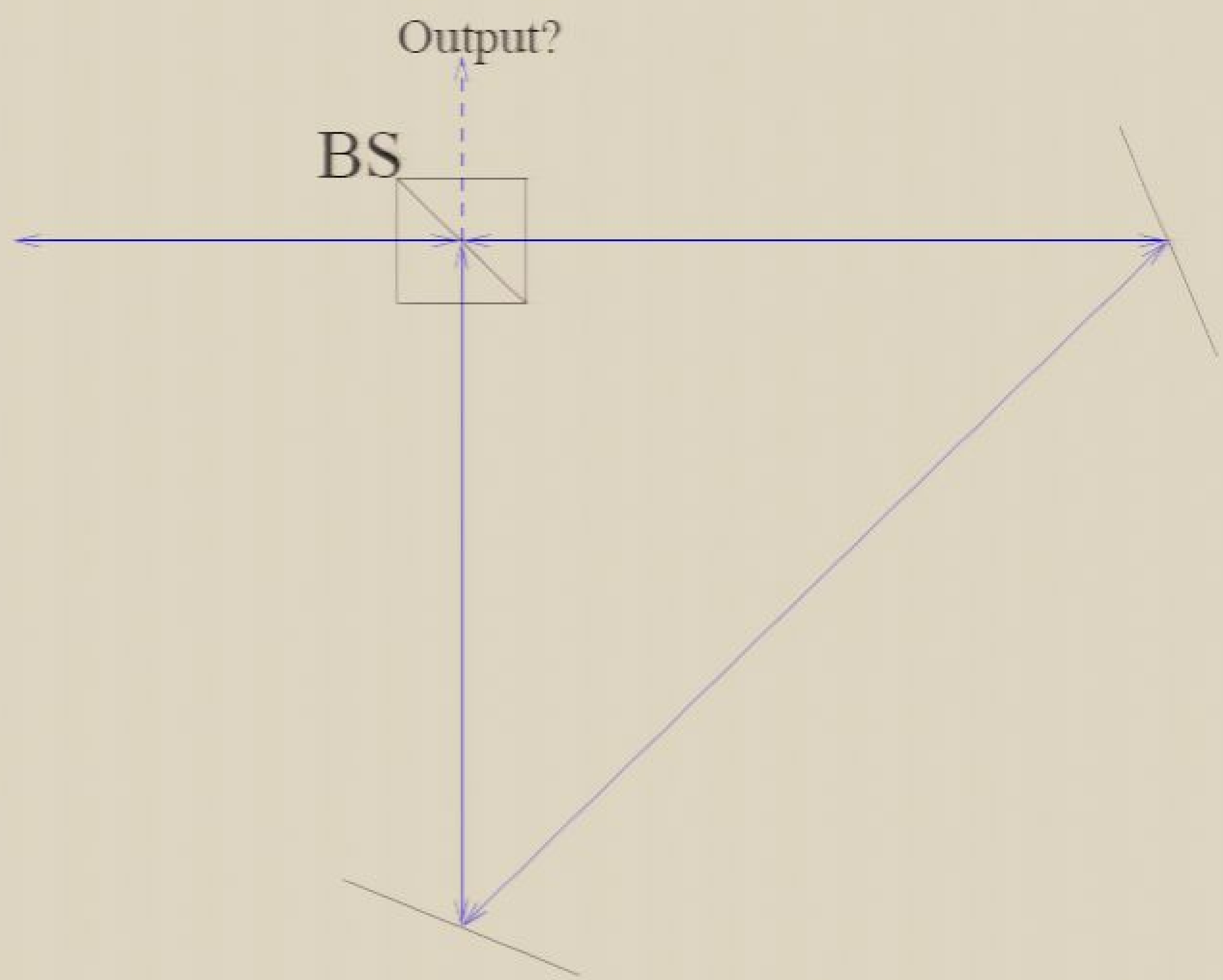
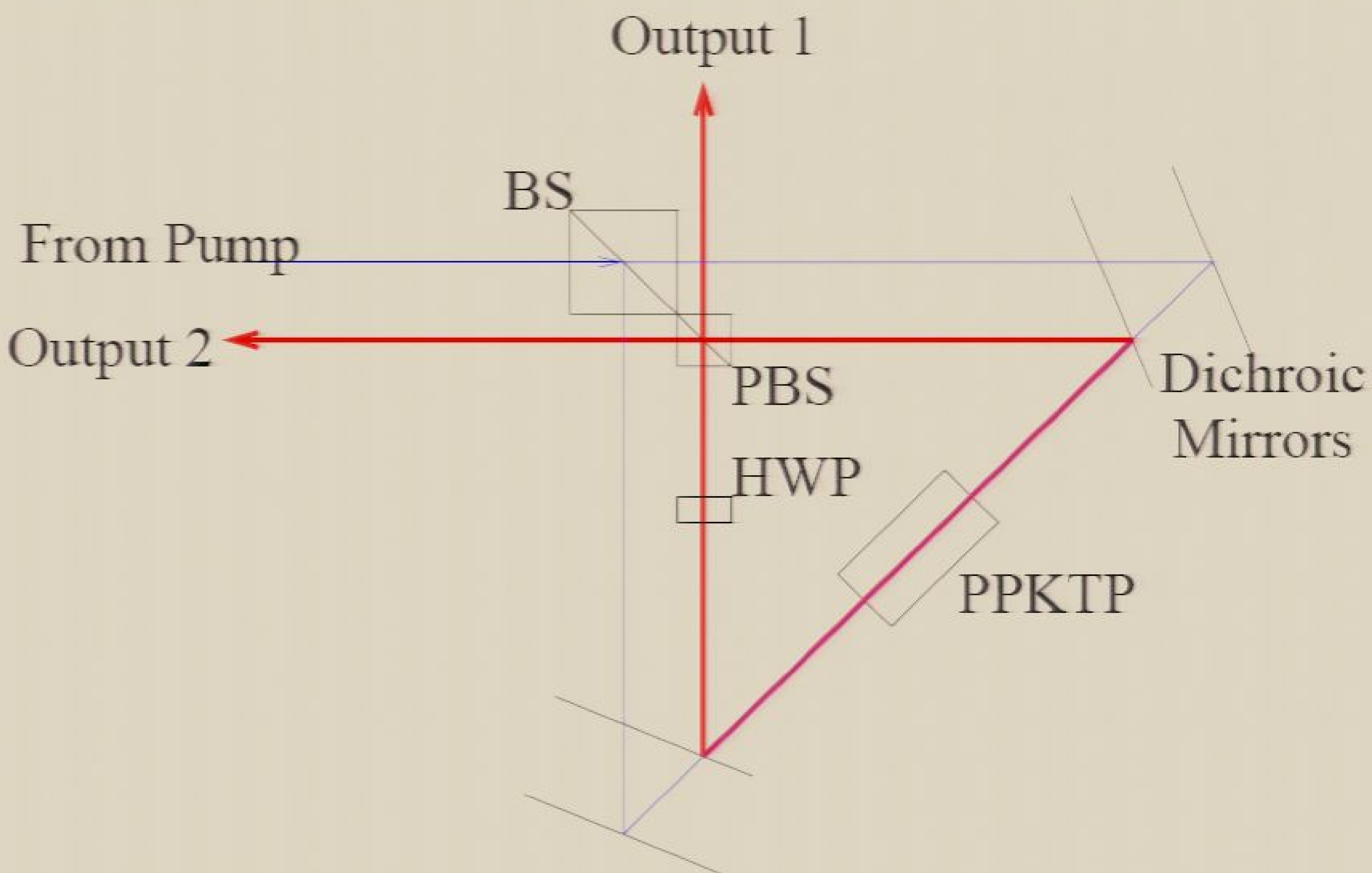
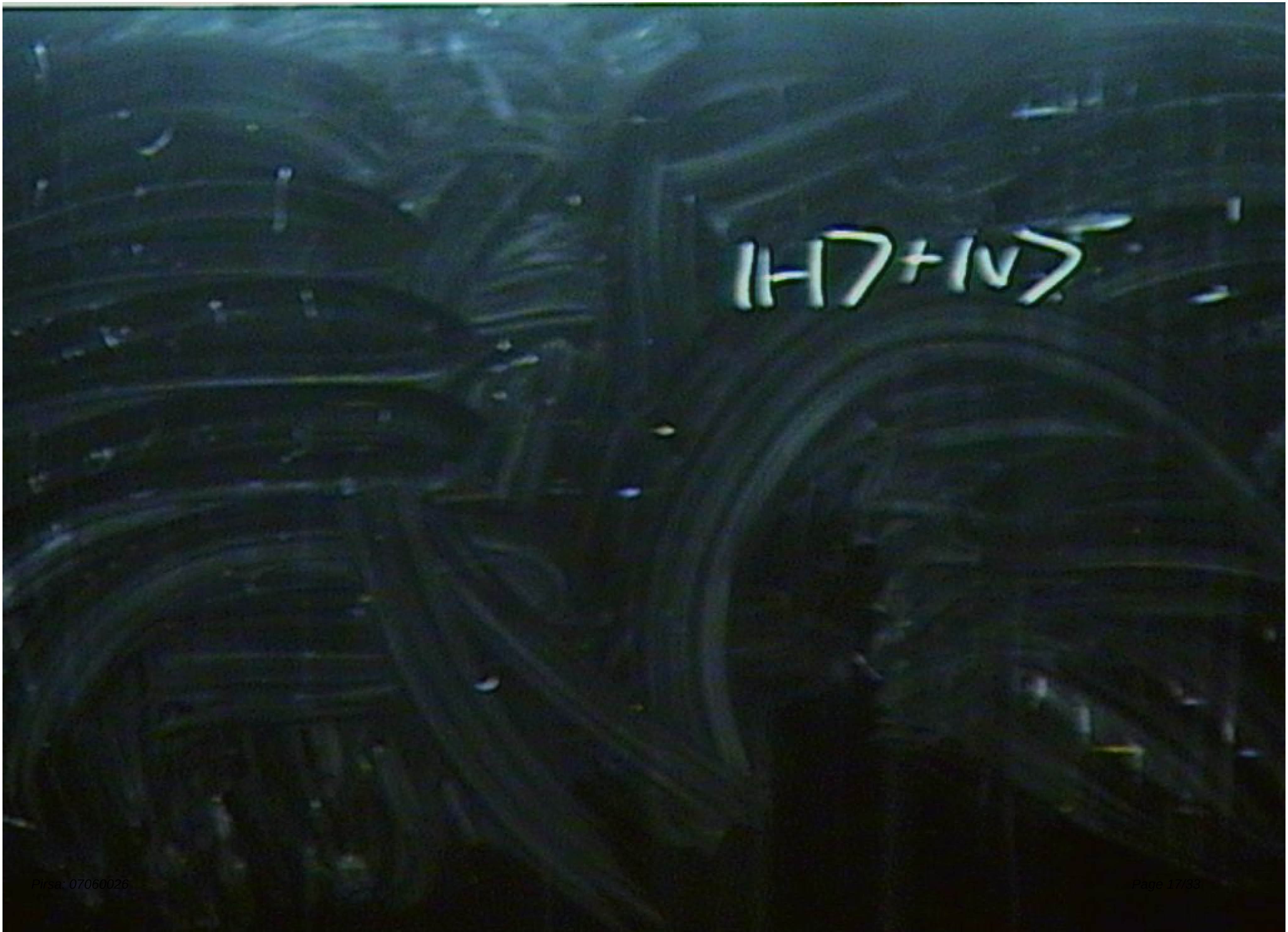
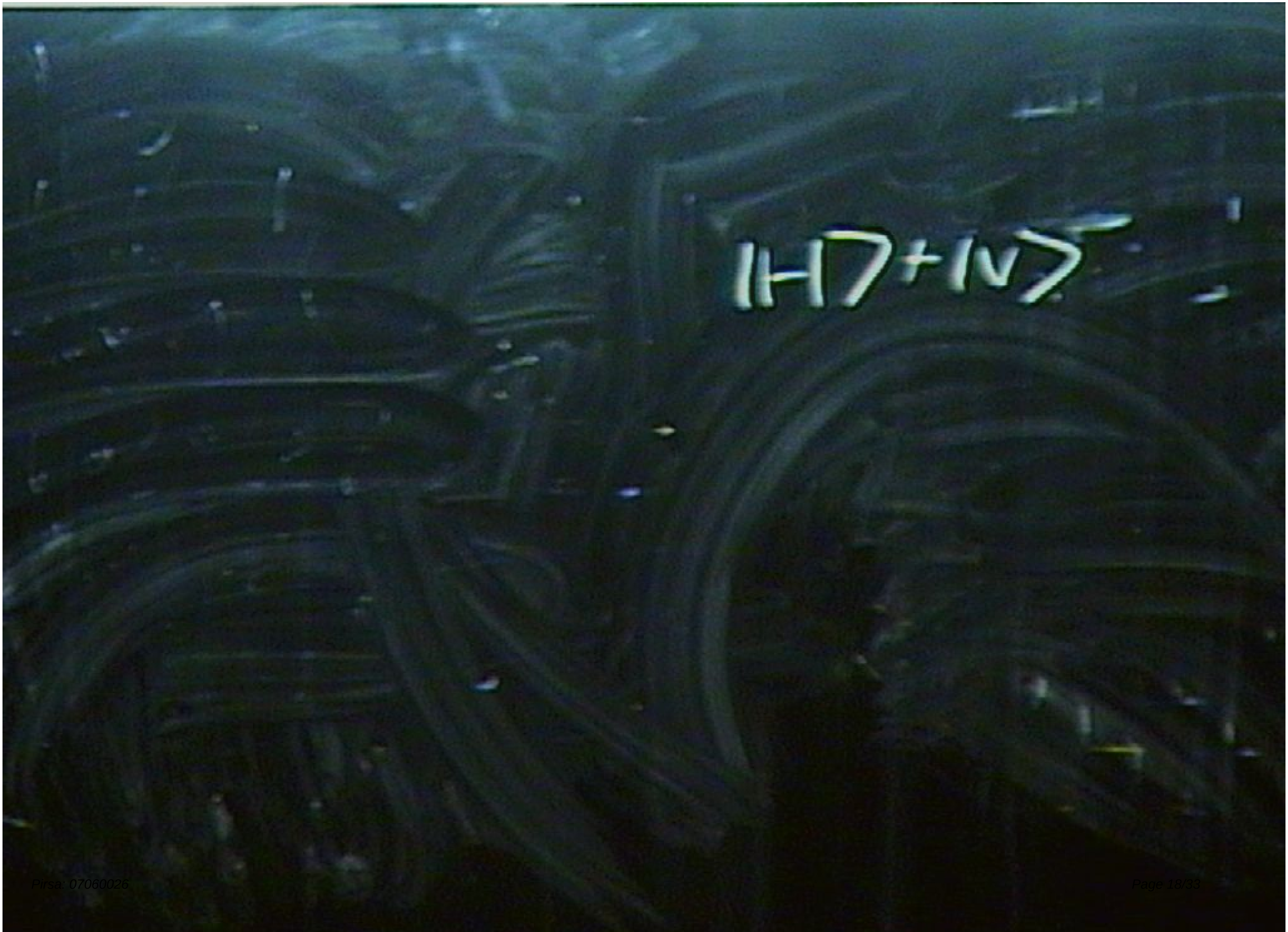


Entanglement!




$|H\rangle + |V\rangle$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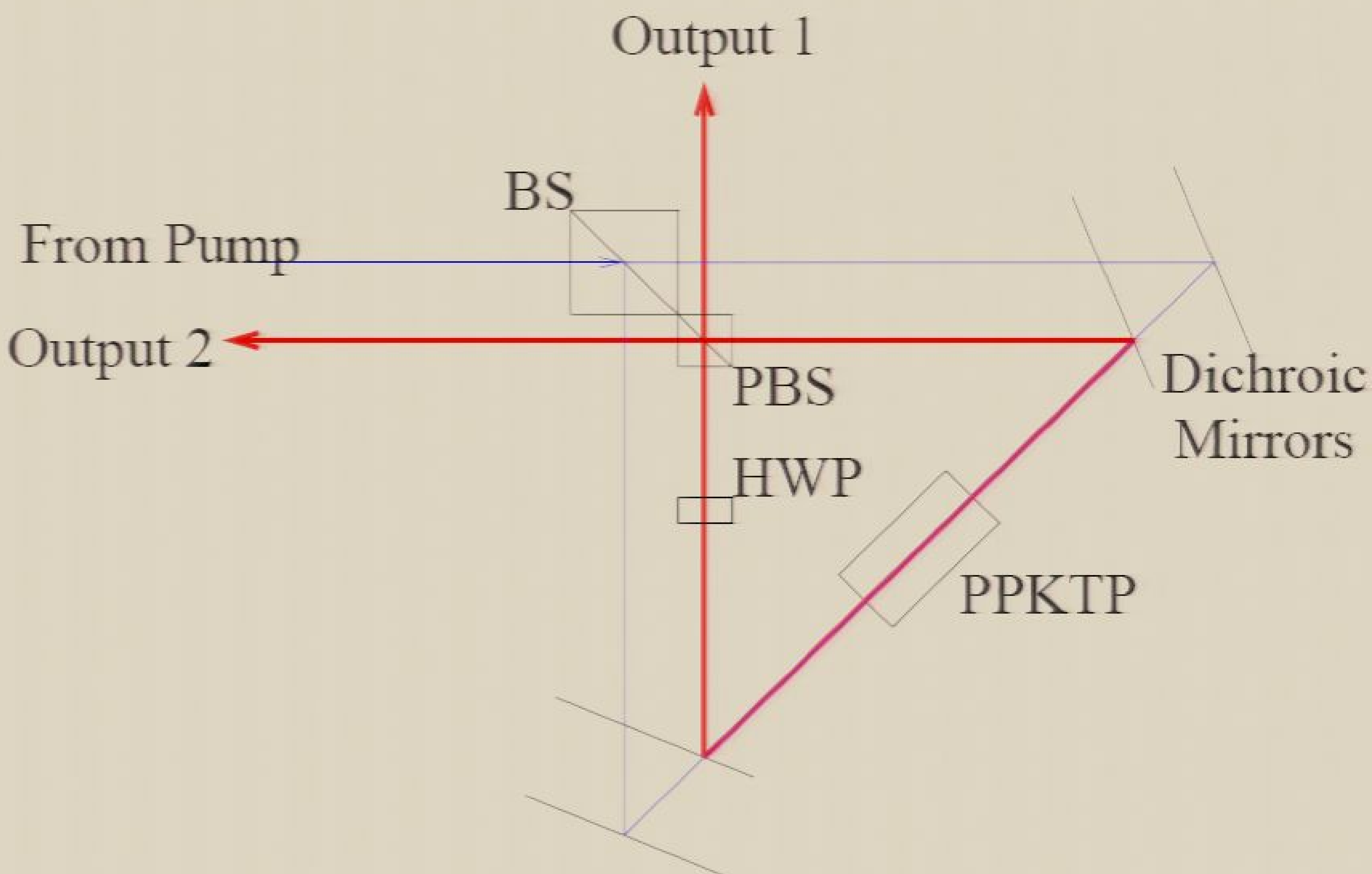
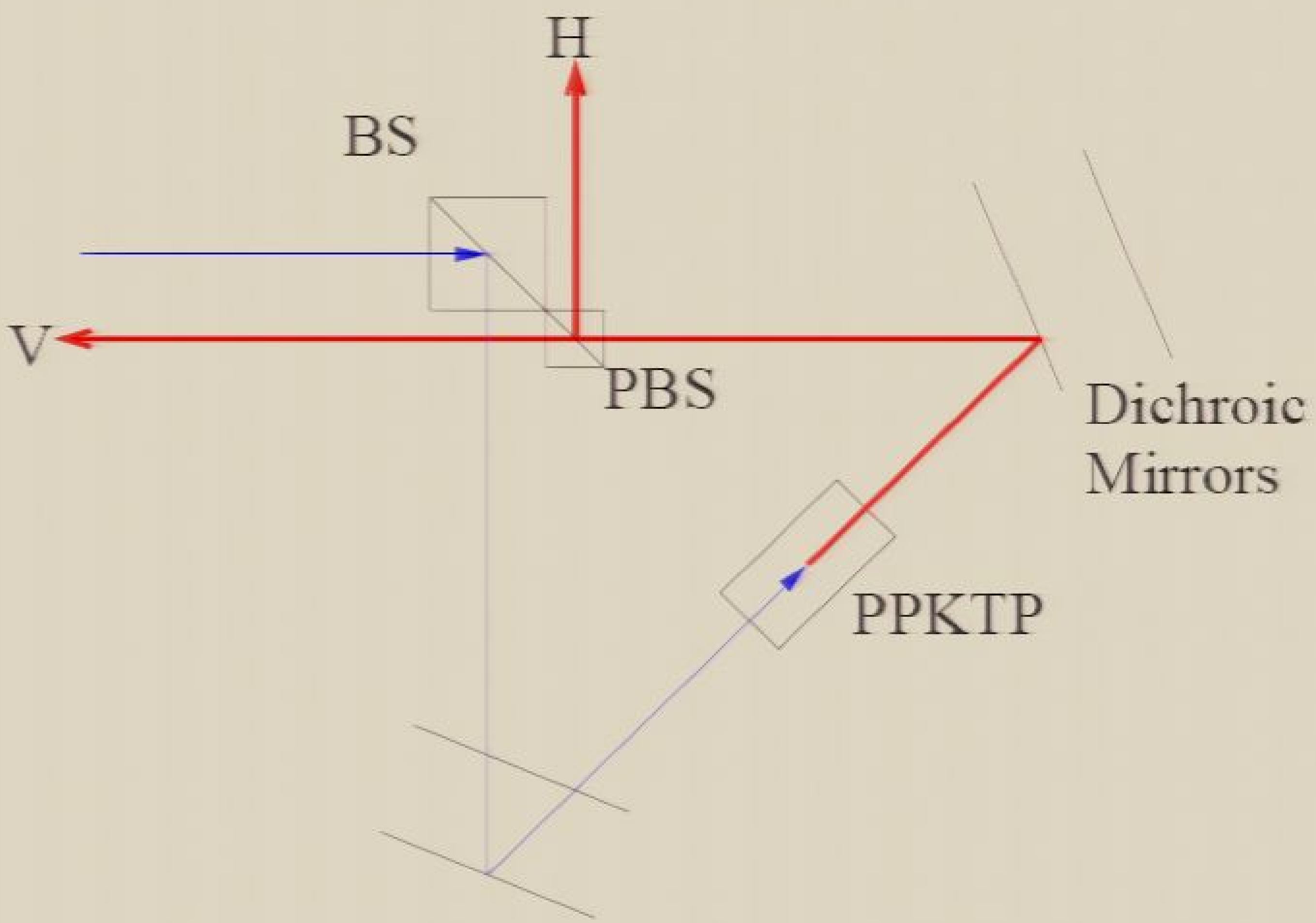


Entanglement!

Counterclockwise path



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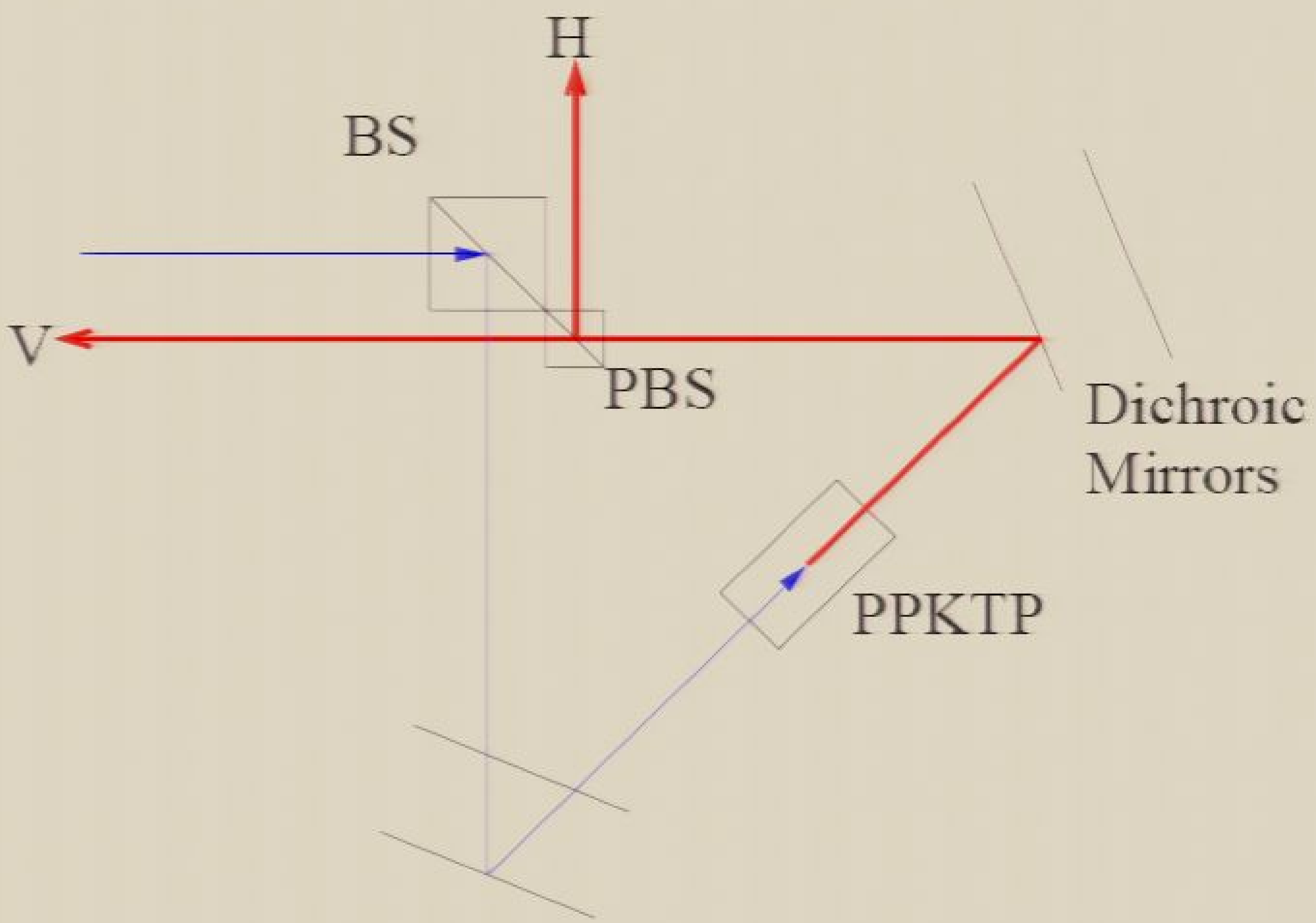

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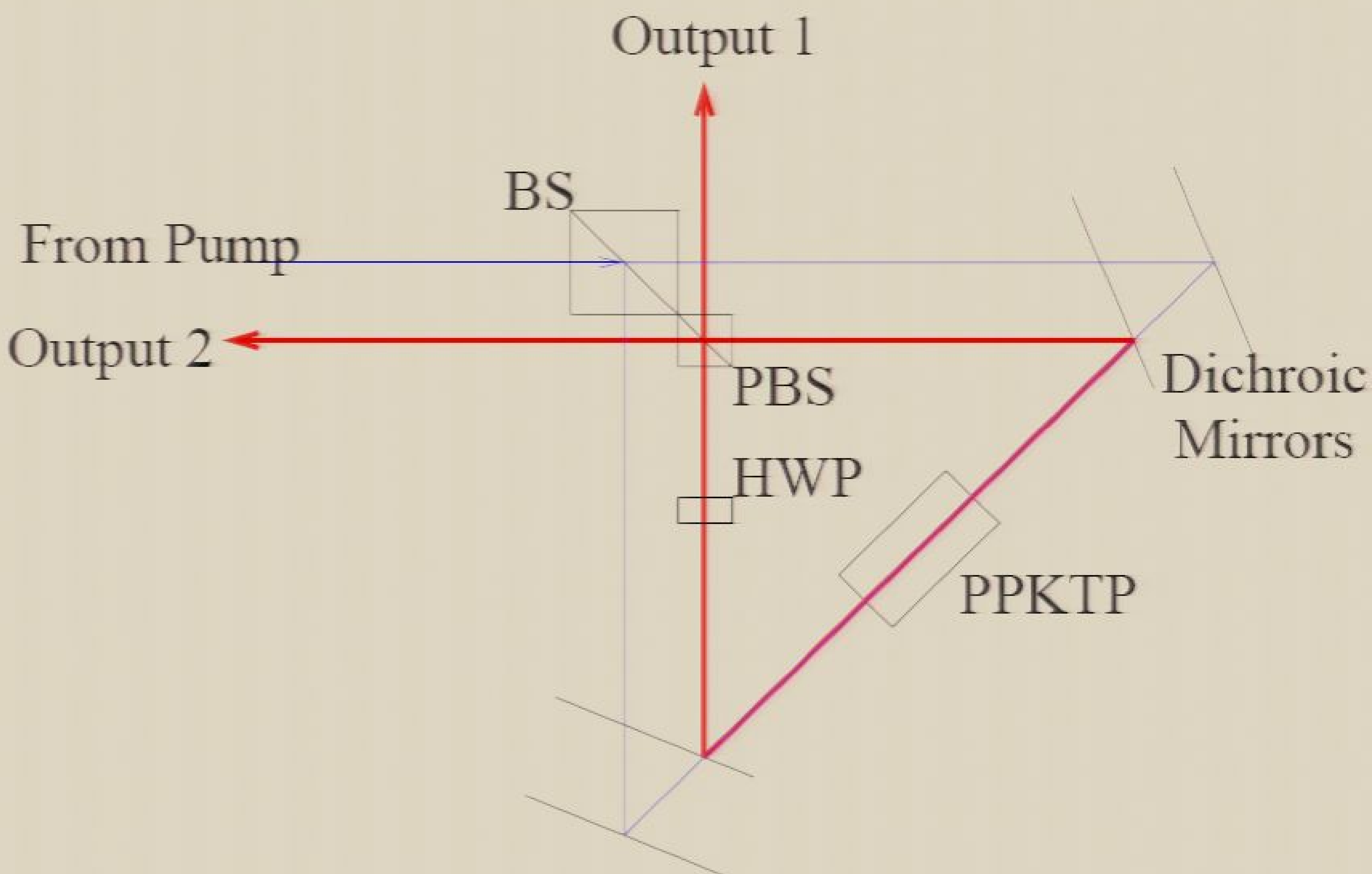
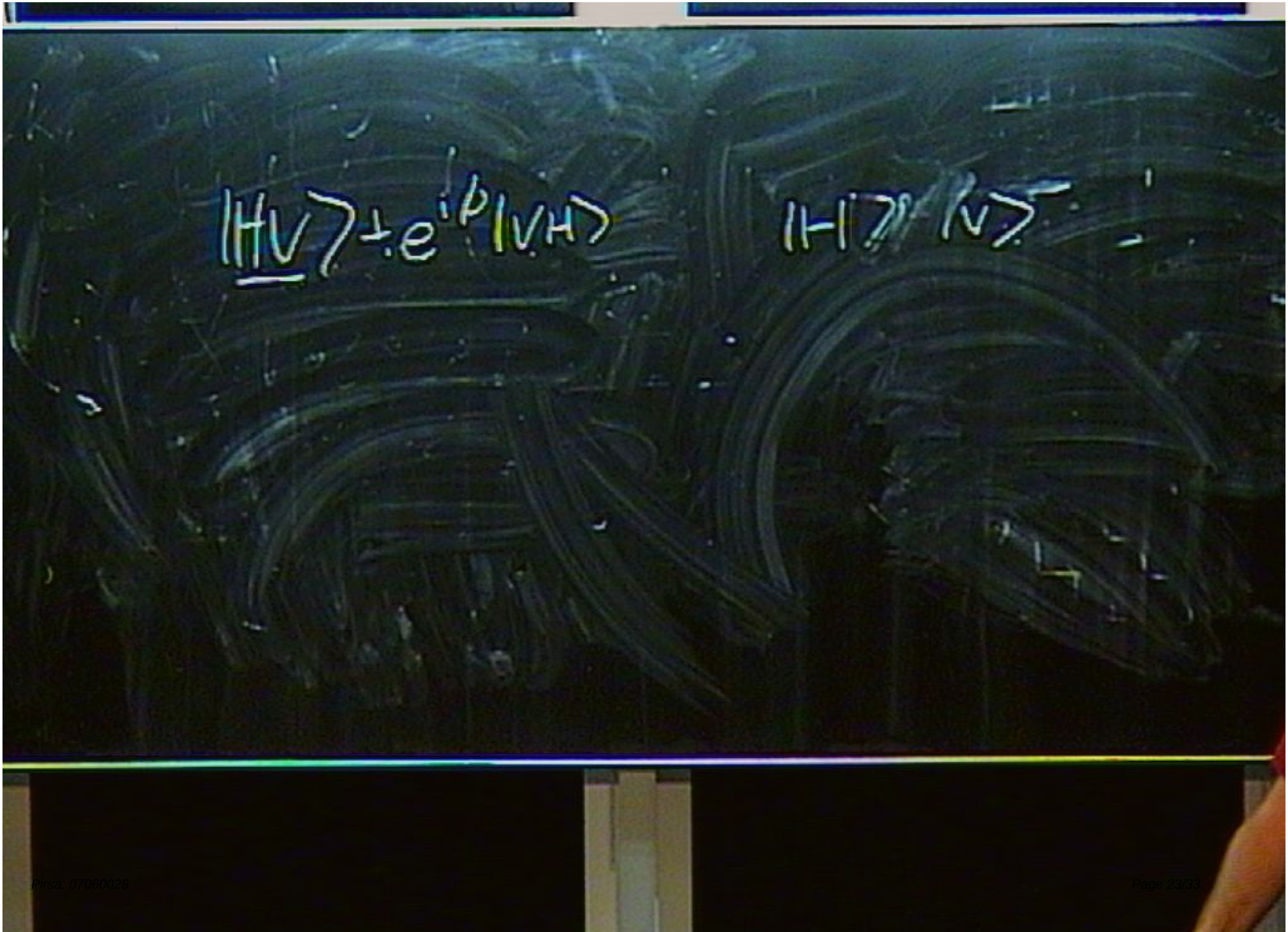
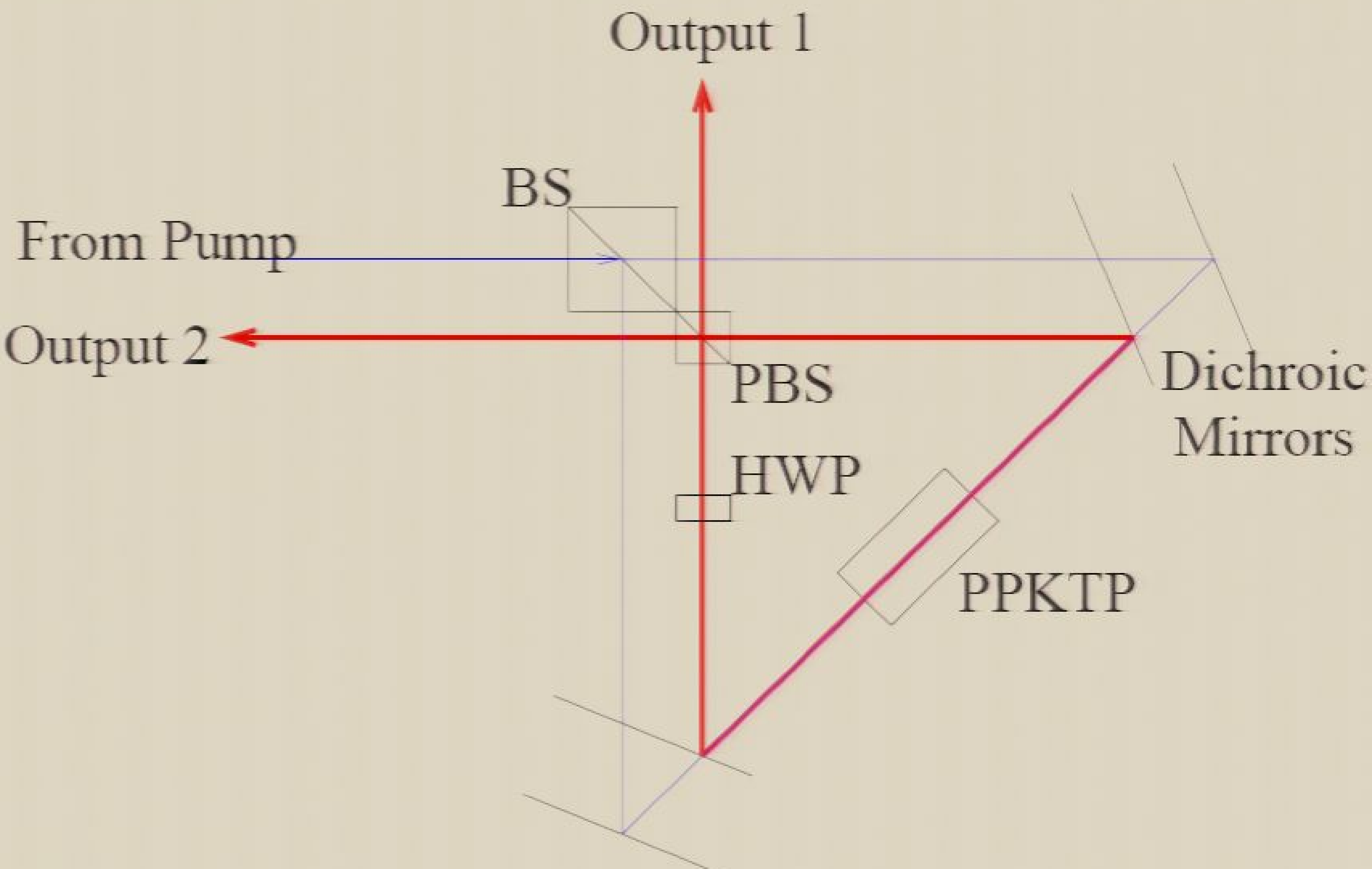
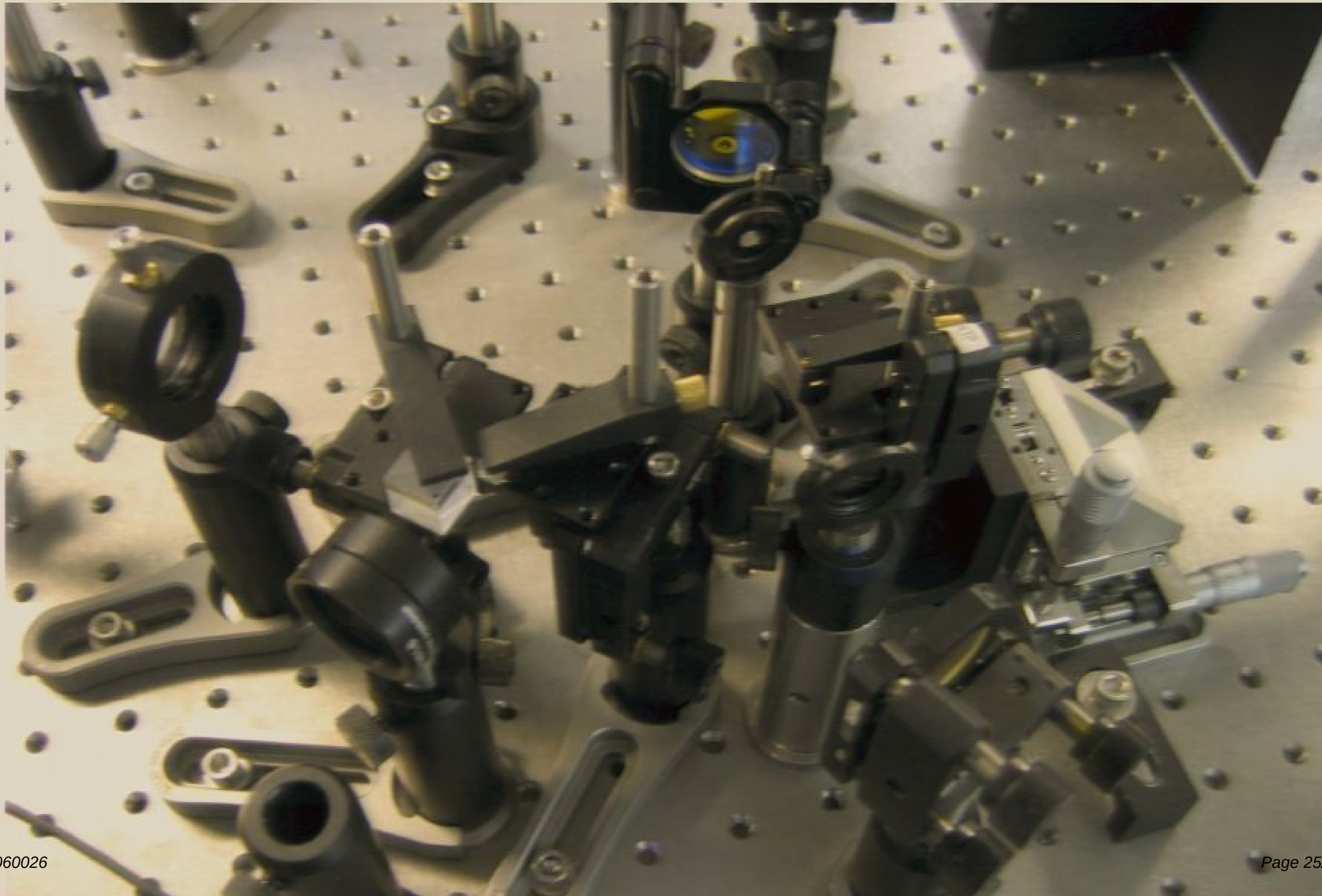



$|HV\rangle \pm e^{i\varphi}|VH\rangle$

Entanglement!



Time for a picture



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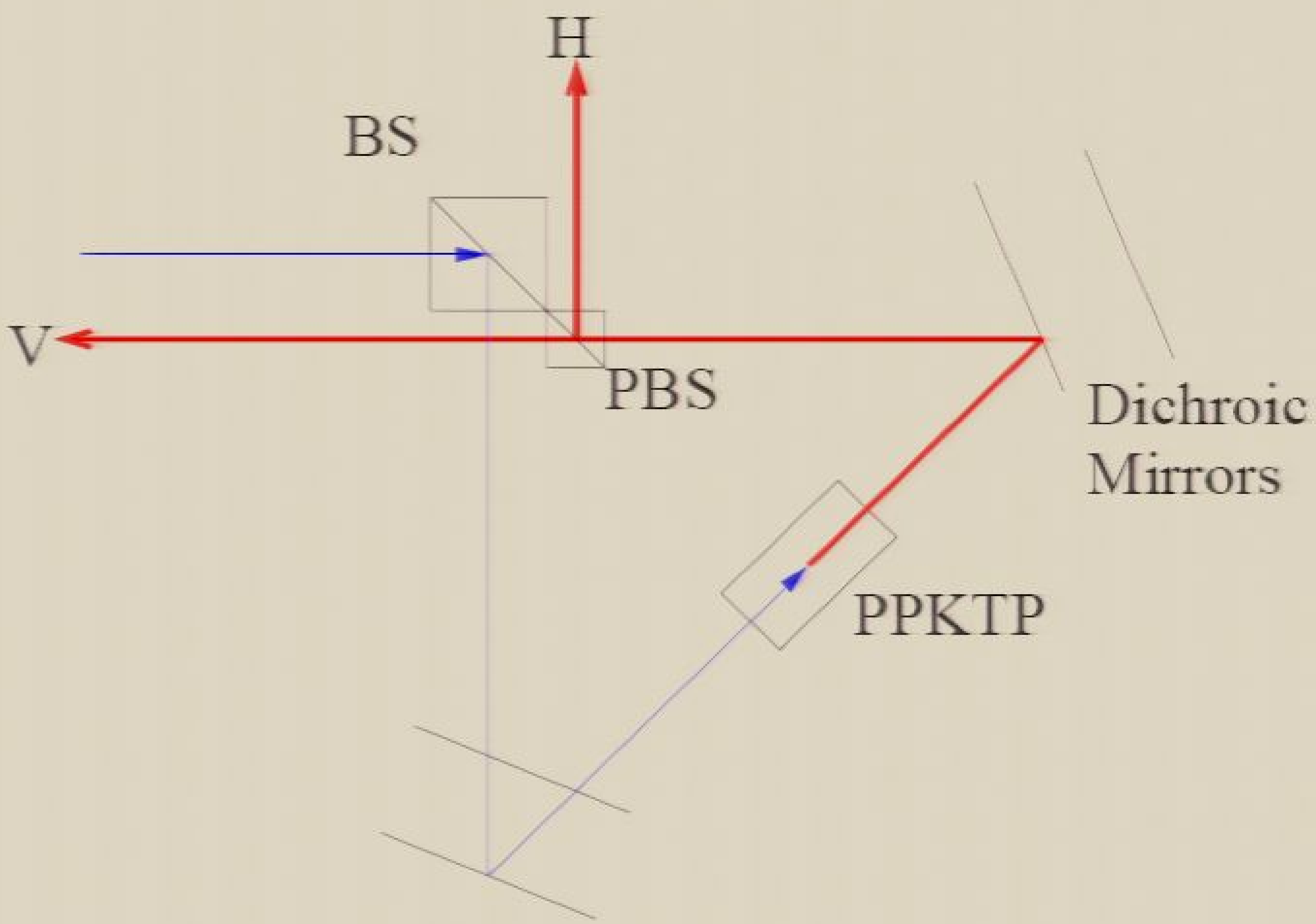

Specifications

For this source, we expect:

- Bandwidth of 9nm for downconverted pairs
- Given a SPDC efficiency of 10^{-10}, 0.1 photon pairs/pulse is attainable
- This implies $7.6 \cdot 10^6$ photon pairs/second

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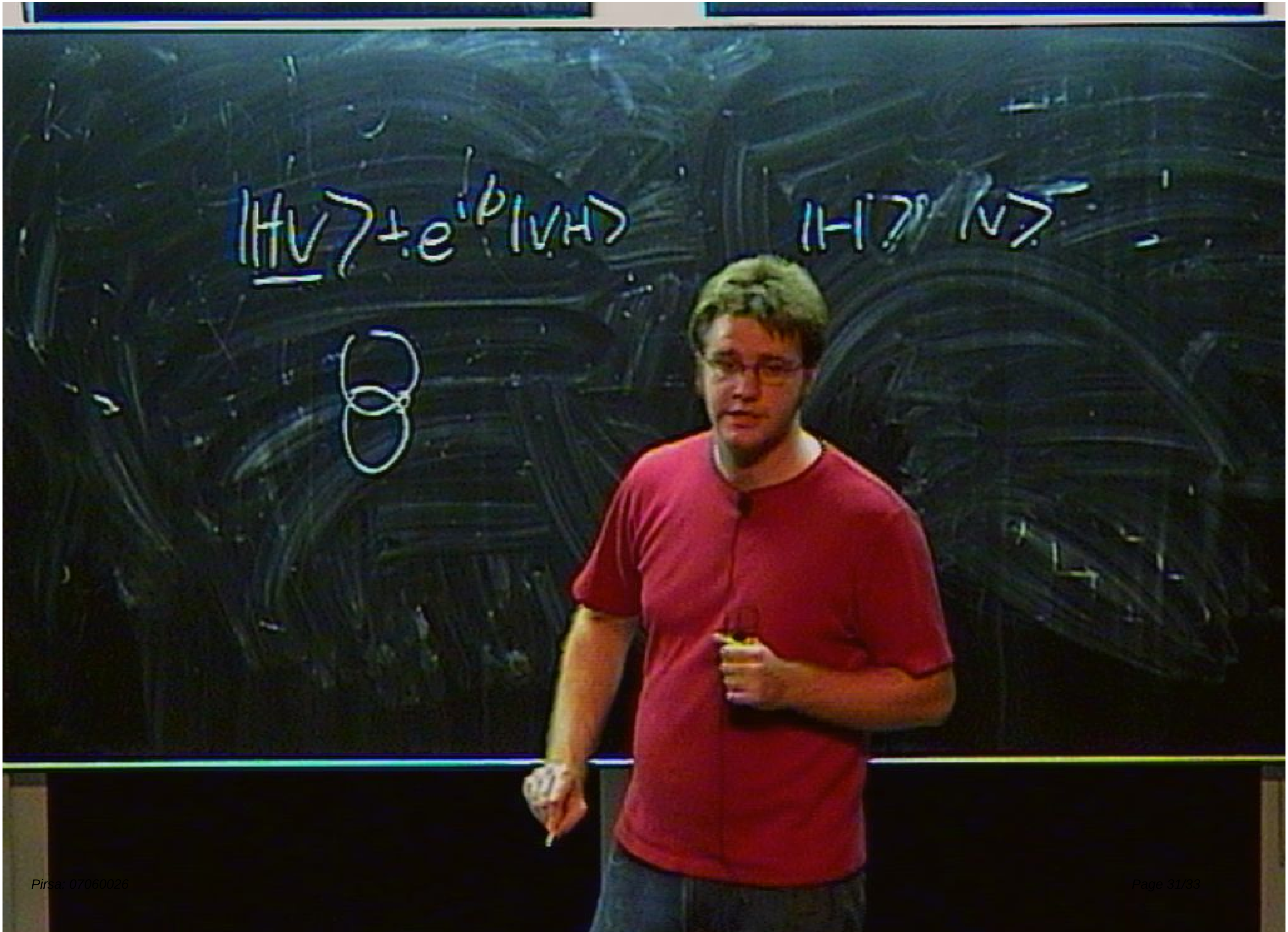
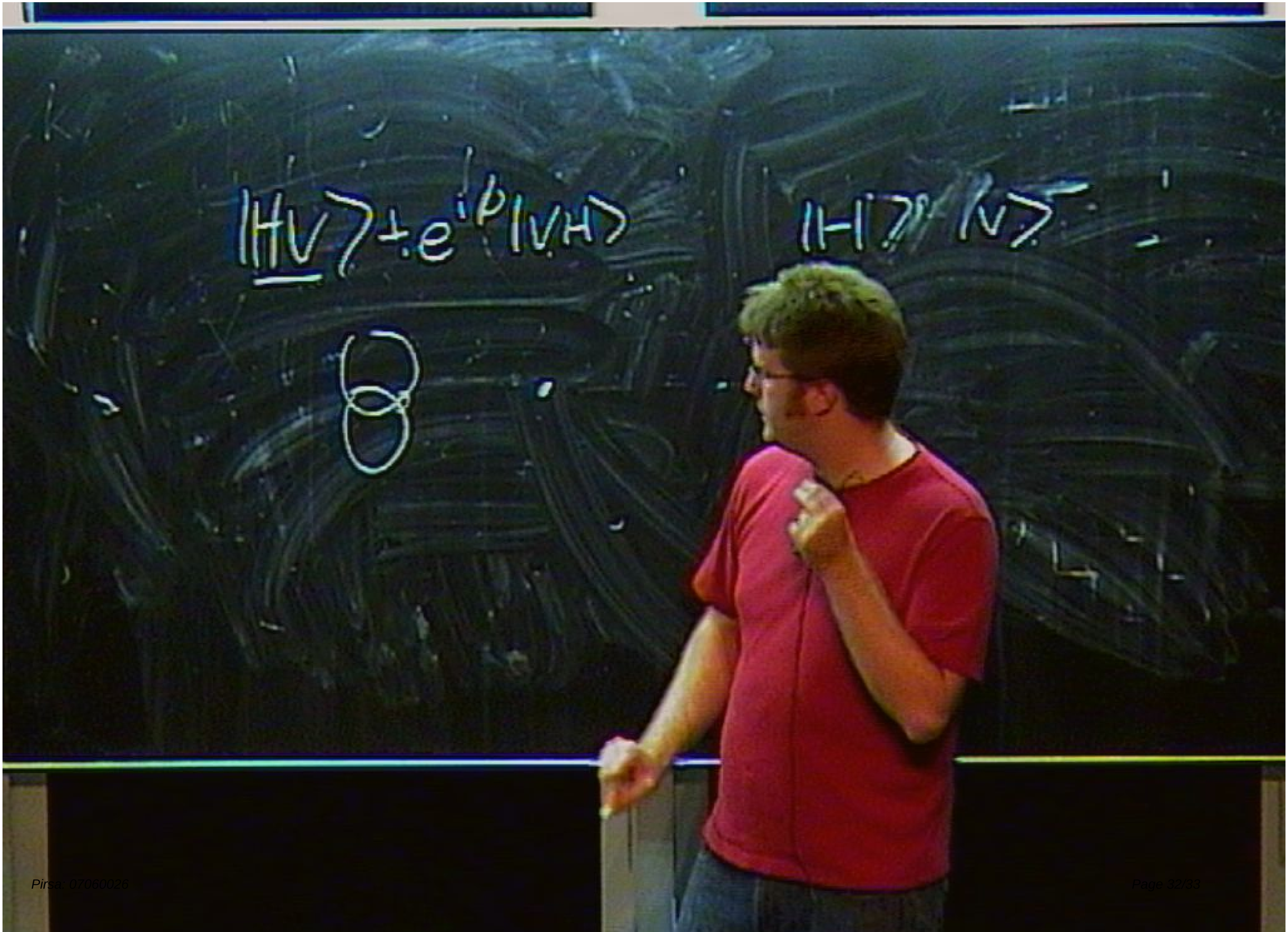
Future plans

- Characterize the source
- Four-fold coincidences
- Substitute these sources for the cone-based ones
- Visibility of entanglement 99%+

Summary

- We can use a Sagnac Interferometer to make a photon pair source
- This source can be bright and of high quality


|HV⟩ + e^{iφ}|VH⟩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Entanglement!