International Journal of Scientific Research in Computer Science, Engineering and Information Technology
ISSN : 2456-3307 (www.ijsrcseit.com)
doi : https://doi.org/10.32628/CSEIT228225

Quantum Multipartite Correlation in Optical Channel

H. R. Sumathi[1], C. Vidya Raj[2]
[1]Department of Information Science and Engineering, JSS Academy of Technical Education Bangalore, Karnataka, India
[2]Professor, NIE college of Engineering Mysore, Karnataka, India
Affiliated to Visvesvaraya Technological University, Belagavi, Karnataka, India

Article Info
Volume 8, Issue 2
Page Number : 168-172

Publication Issue :
March-April-2022

Article History
Accepted: 20 March 2022
Published: 31 March 2022

ABSTRACT

The communication in the quantum networks is based on optical channels to take the advantage of analog, optical and digital communication system. Single data which carries information over the channel can be termed as solid state atoms or photons. The reliable channel is the one which carries the same state from the sending node to destination there can be superposition of states. practically ideal channel does not exist, the optical Gaussian channel which is considered as a degradable quantum channel. The optical interfaces and standard signal format would allow interconnecting fiber optic transmission equipment through multiple networks which carries information generated by multiple users of the network. Taking the infrastructure of existing telecommunication use the quantum information so that it is secure by its nature.

Keywords : Correlation, Entanglement, Photons, Qubits, Teleportation

I. INTRODUCTION

The dual role of light as a particle and wave with double slit experiment have given rise to explore more usage of light photon application in quantum information theory which is the basis for quantum communication. Quantum data is in qubits that can be realized as polarized spin up and down to represent two values $|0\rangle$ and $|1\rangle$ which can be correlated to a 0 and 1 in binary. Quantum entropy was coined by Von Neumann much earlier than the modern classical information theory where Claude E Shannon gave the mathematical proof for current communication technology. For quantum communication Von Neumann entropy is a quantity measure of density operator $S(\boldsymbol{\rho}) = -tr(\boldsymbol{\rho}\log\boldsymbol{\rho})$ quantum channels are governed by completely positive trace preserving maps that relate their output density operator $\dot{\rho}$. The Holevo-Schumacher-Westmoreland theorem developed by them have given the maximum capacity of a typical quantum optical channel $\mathscr{E}$ is given by

$$C=\max(Pi, \mathscr{E}^{\otimes M}(\mathring{\rho}i))$$

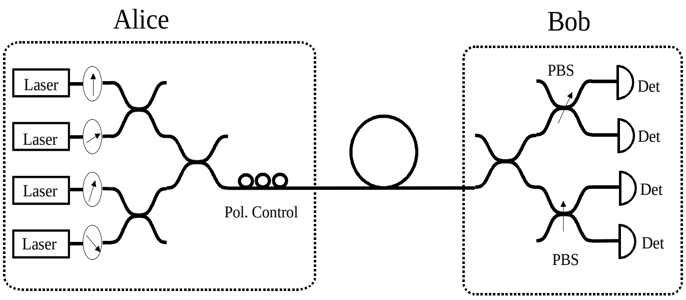

Fig.1

The quantum states are to be the states with quantum phase, it is mandatory for any arbitrary state of the quantum field having the diagonal elements in the density matrix. The value of $\Phi_{\boldsymbol{\theta}}$ is

$\langle n | \Phi_{\boldsymbol{\theta}} | n \rangle = \sum \boldsymbol{\theta}_m | \langle \boldsymbol{\theta}_m | n \rangle |^2$

Coherent states

$\langle \alpha | \Phi_{\boldsymbol{\theta}} | \alpha \rangle = \sum \boldsymbol{\theta}_m | \langle \boldsymbol{\theta}_m | \alpha \rangle |^2$ Where $\alpha = r \exp(i\phi)$

α being a coherent state input, where Ein is a Electromagnetic field and neglecting some decoherence term, as this will not contribute to the ordered correlation functions of the output field itself is the field measured by the past position of the last photon Eout, which is founded by having the driven spin system and the input state. The content information in Fig.1 is a typical sender and receiver using optical cable for the quantum data transfer.

Quantum Correlation

Entanglement are the measure of quantum correlation which is the fundamental basis for quantum communication. The correlations allow many fundamental concepts for the information gain out of a measurement. The generalized function are measured using a correlations $[\boldsymbol{\rho}.\boldsymbol{\tau}]$ and a set of measurements {M}.For every state $\boldsymbol{\rho}$ a classical state $\boldsymbol{\lambda\rho}=\mathscr{M}(\boldsymbol{\rho})$ the calculation is taken, the quantum correlation $Q(\boldsymbol{\rho})=\boldsymbol{\kappa}[\boldsymbol{\rho},\mathscr{M}(\boldsymbol{\rho})]$.The total correlation $\boldsymbol{\tau}(\boldsymbol{\rho})=\boldsymbol{\kappa}[\boldsymbol{\rho},\boldsymbol{\pi}_{\boldsymbol{\rho}}]$ where $\boldsymbol{\pi}_{\boldsymbol{\rho}}$ is the marginals of $\boldsymbol{\rho}$, $\boldsymbol{\pi}_{\boldsymbol{\rho}} = \boldsymbol{\rho}_A \otimes \boldsymbol{\rho}_B \otimes$ -------.Quantum algorithms are having the ability to create and manipulate quantum correlations, Correlations and the superposition of a state play a important role in the quantum field theory. The outcome of quantum field theory is a quantum electro dynamics which gives mathematical proofs for the effects of charged particle at all energy levels.

Multipartite correlation

Every measure of multipartite correlation $\mathcal{G}$, must satisfy i) $\mathcal{G}\geq 0$ for ∀ quantum states ii)$\mathcal{G}=0$ for ∀ bi product states $\boldsymbol{\rho}_A \otimes \boldsymbol{\rho}_B$ iii)Invariant under unitary operations ie $\mathcal{G}(\boldsymbol{\rho})$ iv) $\mathcal{G}(\boldsymbol{\rho})= \mathcal{G}(\boldsymbol{\rho}\otimes\boldsymbol{\pi})$ where $\boldsymbol{\pi}=\boldsymbol{\pi}_a\otimes \ldots\ldots \boldsymbol{\pi}_z$ is a state of completely uncorrelated auxiliary systems. Sharing a multipartite-correlated state ρ, their task is to send ρ using local operations .That is, making ω = ω A ⊗ω B ⊗... be the multipartite state, their task is to act with local operations $\boldsymbol{\lambda} = \boldsymbol{\lambda}$ A ⊗ $\boldsymbol{\lambda}$ B ⊗... onto the state ρ ⊗ ω, and produce σ such that tr 1 (σ) = tr 2 (σ) = ρ. Each sender party not only has to send the local state, but also has to act collectively to transmit the correlations. The advantage associated with quantum algorithms is that it is related to the ability to make a state and make use of quantum correlations.

Quantum Phase Estimation (Kitaev's)

Quantum Phase estimation algorithm is used to find out the eigen value of a unitary operator U that is related to QFT where the period of a function is founded by repeated measurements. A unitary operator Û on the n qubits that has a known eigenstate |u› with an unknown eigen value $\exp(2\boldsymbol{\pi} i\boldsymbol{\phi})$,to find phase $\boldsymbol{\phi}$ with some m qubit, Û produces an overall phase on the state with no observables. The n qubit are left in state |u› with different control bits and get an value of $\cos(2\boldsymbol{\pi\phi})$.By starting the control bit in state $|1\rangle$ a similar estimate $\sin(2\boldsymbol{\pi\phi})$ is obtained. Unitary dilation theorem for multi mode quantum channels are completely positive channel acting on n modes is a bosonic Gaussian channel if it can be realized by invoking $l \leq 2n$ environmental modes E.

Through the expression

$$(\boldsymbol{\rho}^\wedge)=\mathrm{Tr}_E\, [\hat{U}(\boldsymbol{\rho}^\wedge\otimes \boldsymbol{\rho}^\wedge{}_E)\, \hat{U}^\dagger]$$

Where $\boldsymbol{\rho}^\wedge$ is the input n mode state of the system $\boldsymbol{\rho}^\wedge_E$ is a Gaussian state of an environment, Û is a canonical unitary transformation which couples the system with the environment and Tr_E denotes the partial trace over E.

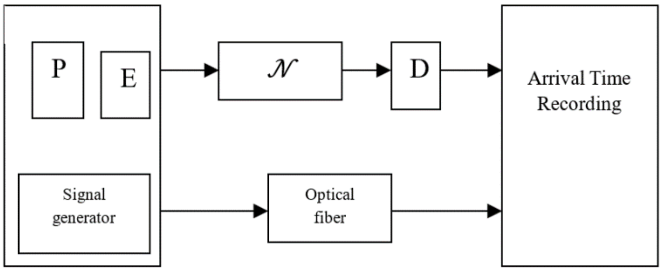

Fig. 2

A quantum communication channel $\mathcal{N}$ is private as shown in Fig,2, if all the possible input messages $\boldsymbol{\rho}_i=|\Psi_i\rangle\langle\Psi_i|$ and with an initial environment $\boldsymbol{\rho}_{Env}$ there exists a set of unitary transformations U_i with probabilities p_i for a perfect protocol

$\sum p_i U_i(|\Psi_i\rangle\langle\Psi_i| \otimes \boldsymbol{\rho}_{Env}) U_i^{+}=1/2I$.The encoding and decoding are done in E and D blocks. The input of the encoder is pure quantum states and maps the quantum states into the joint state of intermediate system is sent through an independent instances of the quantum channel $\mathcal{N}$ and decoded which is a mixed quantum state. The reliable transmission of qubits can be measured by the fidelity of quantum information. The fidelity gives the relation of pure state channel input and received mixed state at the output. Most of the quantum channel are degradable so the output can be viewed by receivers own state. Quantum information sent by quantum channel is private vice versa may not be true.

Wavelength Division Multiplexing

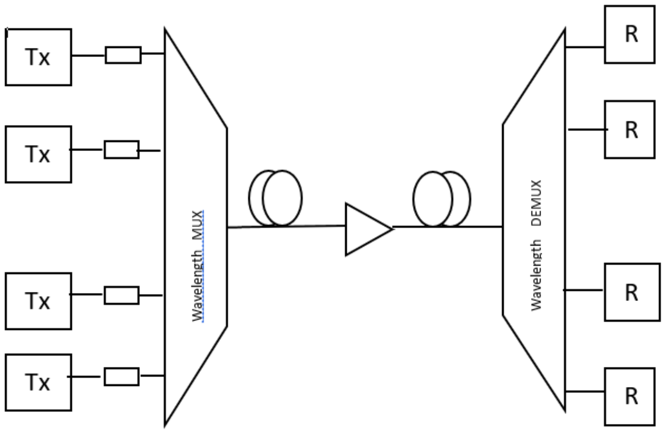

Fig.3

At the transmitters side there are several independently modulated light source each emitting signal source at a unique different wavelength. Multiplexer combine the optical waves into continuous spectrum of signals onto single fiber as shown in Fig 3.In receivers side a demultiplexer is required to separate these optical signals into appropriate detection channels for signal processing the wavelength band occupied by the light signal for small wavelength separation dense wave length division multiplexing given by Telecommunication standard. The wavelength dependent multiplexers using Mach-Zehnder interferometer has three stages splitter, phase shifter and combiner this phase difference are either from a different path length or through a refractive index .For an N to 1 Mach-Zehnder Interferometer multiplexer, where $N=2^n$ with the integer $n \geq 1$ the multipler stages is n and the number of MZIs in stage j is 2^{n-j} .The path difference in an interferometer element of stage j is given by $\Delta L_{stage\ j} = c/2^{n-j} n_{eff} \Delta v$ where n_{eff} is effective refractive index in the waveguide ,c is the speed of light and Δv is the frequency separation of the two wavelengths. The design of WDM requires many optical sources with narrow spectral emission bands one method is to have 'n' lasers each emits at a specific wavelength. Signals from different light sources multiplexed with tolerance requirement and receiving wavelength separated at receiver end. The probability of all the user want to transmit the data at the same time is likely to be less considering the worst case scenario of 100 percent utilization of channel where each user have different wavelength source using round robin type each one will get the quantum time or selecting one user at a time to send data over the shared optical channel. When the user have the information for transmission then only the channel is occupied else it will be idle. The implementation requires devices to combine, isolate, distribute and amplify optical power at different wavelengths. The components include tunable optical filters, sources and amplifiers. As per International Telecommunication Union -T recommendation G.692 specification for WDM specifies that selecting the channels from a range of frequencies referenced to approximately 193.100 THz and spacing them 100 GHz apart about 0.8nm at 1550nm.Suggested alternate spacing of 50GHz and 200GHz which correspond to spectral widths of 0.4 and 1.6nm respectively at 1550nm.

II. CONCLUSION

Entanglement is the technique of photon being teleported from an entangled pair. The transmission between the two system transmitter and receiver reporting the entanglement is the quantum relay, Quantum teleportation is the most promising way to transfer information at a distance. Using optical quantum channel the data emerging from multiple users of the channel are synchronized which enters into a and multiplexed channel with different wavelength. The quantum internet is a collection of transreceiver nodes that can be used as both transmitter and the receiver of quantum data. Quantum repeaters are used for long distance propagation of states from source to destination.

III. REFERENCES

[1]. Aditya Sandor Imre and Laszlo Gyongyosi “Advanced Quantum Communication” an engineering approach IEEE press Wiley publications,(2013).

[2]. Antonio Manzalini TIM Romoli “Quantum Communications in Future Networks and Services”, Via Reiss, 274, 10148 Turin, Italy; antonio.manzalini@telecomitalia.it ; Published: 11 March 2020

[3]. Ion Nechita, Zbigniew Puchała, Łukasz Pawelay and Karol Zyczkowski, “Almost all quantum channels are equidistant” .December 13, 2017

[4]. Chen-Ming Bai1 · Zhi-Hui Li1 · Cheng-Ji Liu1 · Yong-Ming Li2, “Quntum secret sharing using orthogonal multiqudit entangled states” (2017)

[5]. Miguel Orszag, “Quantum Optics”Including Noise Reduction, Trapped Ions, Quantum Trajectories and Decoherence

[6]. Gerd Keiser, “Optical Fiber Communication”

[7]. H.R.Sumathi,Dr C Vidya Raj” Synchronous Optical Network to deliver Quantum Information for Muliple Users” 0973-4562(Print) 1087-1090(Online) Dec-2015 Vol 10,No.86

[8]. H.R.Sumathi,Dr C Vidya Raj “Transferring Quantum Information through the Quantum Channel using Synchronous Multiplexing for Multiple users” International Journal of Next-Generation Networks (IJNGN) 0975-7023(Online)0975-7252(Print)March 2015 Vol 7,No.1 doi : 10.5121/ijngn

[9]. H.R.Sumathi,Dr C Vidya Raj " Quantum Communication Using Orthogonal Quantum Vectors For Multiple Users Over Gaussian Bosonic Channel.” American Journal of Engineering Research (AJER), vol. 7, no. 3, 2018, pp.348-351.

[10]. H.R.Sumathi,Dr C Vidya Raj “Multi Qubit Transmission in Quantum Channels using Fibre optics synchronously and perform Error correction” International Journal of Engineering

and Science Vol 6.Issue 5(May 2016) PP 25-27 ISSN(e):2278-4721 ISSN(p):2319-6483

[11]. Michael A Nielsen & Isaac L. Chuang "Quantum Computation and Quantum Information" Cambridge University Press First South Asian Print,(2002).

[12]. Jeffrey H. Shapiro, V. Giovannetti, S. Lloyd, L. Maccone, J. H. Shapiro, and B. J. Yen,"Capacity of Bosonic Communications" MIT, Research Laboratory of Electronics, Cambridge,USA.NEST-INFM & QUIT,Italy.

[13]. A. S. Holevo, IEEE Trans. Inf. Theory 44, 269 (1998).

[14]. V. Giovannetti, S. Lloyd and L. Maccone and P.W.Shor "Broadband channel capacities", phy Rev A68:062323,2003.

[15]. V. Giovannetti, S. Guha, S. Lloyd, L. Maccone, J. H. Shapiro, B. J. Yen, and H. P. Yuen, "Classical capacity of free-space optical communication," in O. Hirota, ed. Quantum Information, Statistics, and Probability ,Rinton Press, Princeton, (2004)

[16]. Navneet K Sharma and Anirban Pathak, "Bosonic channel capacity of a Non linear dispersive optical fiber"(2008)

Cite this article as :

H. R. Sumathi, C. Vidya Raj, "Quantum Multipartite correlation in Optical channel", International Journal of Scientific Research in Computer Science, Engineering and Information Technology (IJSRCSEIT), ISSN : 2456-3307, Volume 8 Issue 2, pp. 168-172, March-April 2022. Available at doi : https://doi.org/10.32628/CSEIT228225
Journal URL : https://ijsrcseit.com/CSEIT228225