**\subsection{Superdense coding}**

The idea of quantum dense coding was introduced by Bennett and Wiesner [Phys. Rev. Lett. 69, 2881], which can be used to send two bits of classical information using only one particle in a Bell state. In 1996, Mattle et al. [Phys. Rev. Lett. 76, 4656 (1996)] realized quantum dense coding experimentally for the first time in photonic system. However, they cannot realized a complete Bell-state analyzer, only three different messages could be encoded by a single qubit. Thus, an increase of channel capacity to  bits was possible.

To distinguish between all four polarization Bell states of two photons, Schuck et al. [Phys. Rev. Lett. 96, 190501 (2006)] developed a method that using hyperentangled source to realize a complete linear-optical Bell state analyzer in 2006, and achieved an overall channel capacity of 1.18(3) bits per photon in their experiment. In 2008, Kwiat's group [Nature Phys. 4, 282 (2008)] achieved channel capacity of 1.63 bits using pairs of photons simultaneously entangled in spin and orbital angular momentum, successfully beating the channel capacity limit for linear photonic superdense coding.

In other aspect, due to the noises in channel, researches hope to successfully achieve high efficiency dense coding over the noise channel. In 2013, A. Chiuri et al. successfully demonstrated dense coding over a depolarising channel [Phys. Rev. A, 87 (2013) 022333]. In 2014, Liu et al. [Europhysics Letters, 114(1), 10005(2016)] developed a superdense coding protocol in the presence of non-Markovian noise, they proved that loss of entanglement during encoding procedure will not reduce efficiency of information transmission. Their experiment reached the values of mutual information close to 1.52±0.02 (1.89±0.05) with 3-state (4-state) encoding.

Besides photonic system, superdense coding are also implemented in other systems, such as NMR system [Phys. Rev. A 61, 022307 (2000)] and atomic qubits [Phys. Rev. Lett. 93, 040505 (2004)]. In 2002, Li et al. [Phys. Rev. Lett. 88, 047904 (2002)] realized quantum dense coding by using continuous variables optics.

**\subsection{Quantum secret sharing}**

In 1999, Richard Cleve, Daniel Gottesman, and Hoi-Kwong Lo firstly proposed the concept of quantum secret sharing [Phys. Rev. Lett. 83, 648 (1999)]. Quantum secret sharing can enhance the security of classical information. In 2001, Gisin's group demonstrated the protocol for the first time based on energy-time entanglement, and this is also the first application of a quantum communication protocol based on more than two qubits [Phys. Rev. A 63,042301 (2001)]. In 2005, Jianwei Pan's group developed an ultra-stable four-photon GHZ states, and then realized 3-party quantum secret sharing [Phys. Rev. Lett. 95, 200502 (2005)]. In the same year, Weinfurter's group proposed and demonstrated a new quantum secret sharing protocol by sequential transformation of single qubit, without involving multiparticle GHZ states [Phys. Rev. Lett. 95, 230505 (2005)]. In 2007, Weinfurter's group realized four-party quantum secret sharing for the first time via the resource of four-photon entanglement [Phys. Rev. Lett. 98, 020503 (2007)]. In 2014, Tame's group realized four-party graph-state quantum secret sharing with a five-qubit graph state, which is meaningful to the integration of quantum networks via the measurement-based paradigm .[Nat. Commun. 5, 5480 (2014)].

The protocol can also be utilized as distribute quantum state securely, named as quantum state sharing. In 2004, Lam 's group demonstrated a multipartite protocol to securely distribute to 3 parties and reconstruct a quantum state with a fidelity average of 0.73 [Phys. Rev. Lett. 92, 177903 (2004)].

Theoretically, quantum secret sharing should satisfy three criteria: reliability, confidentiality [Commun. ACM 22, 612 (1979)] [G. R. Blakley, Safeguarding cryptographic keys, in Proc. Of the National Computer Conference, 1979, Vol. 48 (1979), p. 313], and capability of sharing entangled states. However, the experiments stated above cannot satisfy the second and third criterions simultaneously. In 2016, Jianwei Pan's group realized the fully quantum secret sharing, satisfying all of the three criteria simultaneously [PRL 117, 030501 (2016)].