Homework questions IDEA QIP course - Hanson lectures

1. For each of the following applications, give two pros and two cons of NV centers compared to other systems:
a. sensing

+ nanoscale: high spatial resolution
+ long spin coherence time: good sensitivity
+ can sense multiple quantities: magnetic fields, electric fields, temperature
+ easy to operate: room-temperature operation, single laser operation
+ diamond is non-toxic

- readout (at room-temperature) not single-shot
- need laser for readout: limitation for certain samples

b. quantum computing

+ long coherence times
+ don't need dilution fridge ("just" 4K)
+ long-range coupling between qubits possible
+ classical processing can be done at room temperature

- no well-established path of nanofab to make deterministic array of spins
- NV-NV coupling via photons currently too slow due to spectral properties; need optical cavities

c. quantum communication/quantum internet

+ long coherence times
+ intrinsic local qubit register
+ hybrid architecture very suitable for different network tasks: generate entanglement vs local storage and processing

- need cryogenics (4K)
- NV-NV coupling via photons currently too slow due to spectral properties; need optical cavities

2. Download the following four quantum teleportation papers:

1. Monroe, trapped ions: http://arxiv.org/abs/0907.5240
2. Rempe, trapped atoms: http://arxiv.org/abs/1212.3127
3. Zeilinger, photons: http://arxiv.org/abs/1403.0009
4. Hanson, NV centers: http://arxiv.org/abs/1404.4369

For each of these, answer the following questions:

a. what is the probability that teleportation succeeds per attempt?

1. $P=2.2*10^{-8}$
2. $P=0.001$

3 This is hard to get from the paper, as the teleported qubit is transported over a long distance and has more than 30dB loss.
4 P=1, once the entanglement is established, the protocol is fully deterministic.

b. what is the fidelity of the teleported states (conditioned on a sign of success)?
1. F=90%
2. F=79% up to F=88% for strict photon selection (and thus lower success rate)
3. F=83%
4. F=86%

c. what is the rate at which teleportation succeeds?
1. Once per 12 minutes= once per 720s.
2. Once per 0.1s
3. They report 605 coincidences in 6.5 hours, which is roughly 1 event per 100s.
4. The teleportation protocol is limited by the entanglement generation which succeeds once per 250s.

d. what is the distance over which the quantum state is transferred? In other words, what is the distance between alice and bob when teleportation takes place? Be careful here: the moment of teleportation is the moment that Alice performs the Bell state measurement, thus collapsing the state (up to some rotation) onto Bob's qubit.
1. 1 meter
2. 21 meter
3. The authors note that Bob's qubit is still in the local fiber when the Bell state measurement is performed: the teleportation is therefore performed locally, probably over a distance of a few meters. After that time, the teleported qubit just travels alongside the classical information across the water. Another way to look at it is that the required entanglement is shared between particles that are never more than a few meters apart.
4. 3 meter