

Qudits of Multi-Single Slits, Multi-Double Slits and Multi-Triple Slits --- Corresponding to Octal System, Decimal System, Duodecimal System, Hexadecimal System

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Abstract One of tasks of quantum computing research is to reduce the components utilized for reaching certain computation power. To significantly reduce the components, we propose four kinds of Qudits of higher-dimension, multi-folds higher than the two-dimension of the qubits, which are respectively formed by: (1) multi-single-slits; (2) multi-double-slits (multi-Qubits); (3) multi-triple-slits (multi-Qutrits); and (4) combination of above. The further advantage is that the so formed Qudits may adopt Octal Number System, Decimal Number System, Duodecimal Number System, and Hexadecimal Number System, respectively.

Keywords: qudits, qubits, qutrits, single slit, double slit, triple slits, Octal system, Decimal system, Duodecimal system, Hexadecimal system

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1. Introduction

The quantum mechanics and the digital computer are the significant theory and the powerful technology respectively. In 1980s, Feynman [1] suggest that quantum theory might be applied in computer technology. In 2019, Google-NASA build a 54-qubit quantum computer [2]. IBM introduced IBM Q quantum computer in 2020 [3].

Recent developments in the quantum computation are: (1) the entanglement of individual molecules is achieved, which may have significant applications in quantum computing [4]; (2) "quantum circuits" were created that correct errors more efficiently [5,6].

To achieve certain computing power, one of tasks of quantum computing research is to reduce the components.

The n qubits have the computing power of 2^n [7]. One double slit has two slits and 2 basic states. The double slit experiment paves the way toward a novel strategy for quantum computing [8]. One triple slit has three slits and 3 quantum states. The n qutrits have the power of 3^n [9,10].

Qudits can encodes more than three states. Qudits computer can reach more computing power than the qubit computer with less Qudits components.

In this article, we propose the higher dimension Qudits system formed by utilizing multi-single slits, multi-double slits, multi-triple slits and combination of above, respectively. We utilize the notation Qudits- x/y to present

a qudits that contains x slit and y basic states, where $x = 1, 2, 3$ and $1-2-3$ stands for that the Qudit is formed by multi-single slits, multi-double slits, multi-triple slits and combination of above, respectively. The " y " is the states.

The proposed Qudits not only have more basic states, much higher dimension, to reduce the number of the Qudits utilized for reaching certain computation power, but also can adopt the number systems beyond the binary system: Qudits-1/8 and Qudits-2/8 correspond to Octal number system, respectively. Qudits-1/10 and Qudits-2/10 correspond to Decimal number system, respectively. Qudits-1/12, Qudits-2/12 and Qudits-3/12 correspond to Duodecimal number system, respectively. Qudits-1/16 and Qudits-2/16 correspond to Hexadecimal number system, respectively.

2. Qudits-1/y System

Now let us consider several examples of Qudits-1/ y , which is formed by multi-single slits (Figure 1).

Qudits-1/8 system has eight single slits and thus, 8 states,

$|\psi\rangle = \alpha_0|0\rangle + \alpha_1|1\rangle + \dots + \alpha_7|7\rangle$. Where $\sum_i |\alpha_i|^2 = 1$. To get power $(8)^m = 2^{1000}$, we need 334 of qudits-1/8, which would be able to perform as many operations as 1000 qubits.

Qudits-1/16 system has 16 single-slit and 16 states. To get power $(16)^m = 2^{1000}$, we need 250 of qudits-1/16.

Qudits-1/24 system has 24 single slits and 24 states. To get power $(24)^m = 2^{1000}$, we need 219 of qudits-1/24.

Qudits-1/36 system has 36 single slits and 36 states. To get power $(36)^m = 2^{1000}$, we need 194 of qudits-1/36, namely 194 of qudits-1/36 would be able to perform as many operations as 1000 qubits.

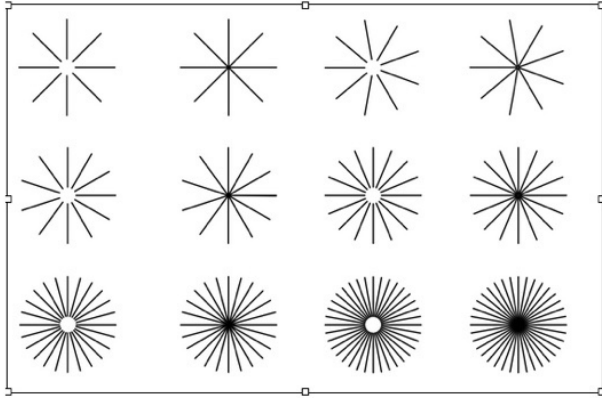


Figure 1. Multi-single slits

Figure 2 shows how many Qudits formed by different number of single slits are needed for reaching power of 2^{1000} .

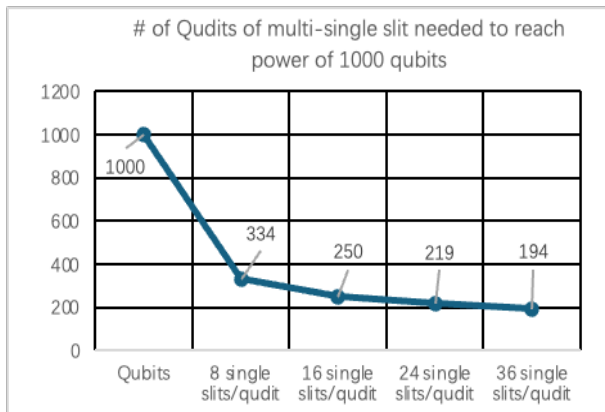


Figure 2. Qudits (multi-single slits) vs qubits

The more single slits a Qudit contains, the less Qudits are needed to reach the power of 2^{1000} .

Another feature of Qudits is that Qudits-1/8 can form Octal number system. Qudits-1/10 can form Decimal system. Qudits-1/12 can form Duodecimal number system. Qudits-1/16 can form Hexadecimal number system.

3. Qudits-2/y System

Now let us consider several examples of Qudits-2/y formed by multi-double-slits (multi-Qubits) (Figure 3).

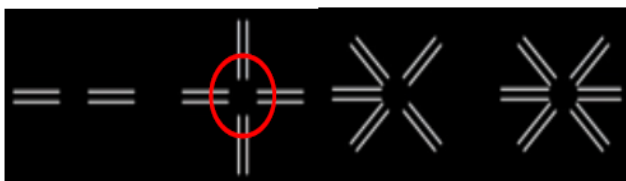


Figure 3. Qudits of multi-double slits

Qudits-2/4 system has two double slit and 4 states,

$|\psi\rangle = \alpha_0|0\rangle + \alpha_1|1\rangle + \alpha_2|2\rangle + \alpha_3|3\rangle$. Where $\sum_i |\alpha_i|^2 = 1$. To get the computing power of 1000 Qubits, $4^m = 2^{1000}$, we need 500 of qudits-2/4.

Qudits-2/8 system has Four double slit and 8 states. The red circle shows the area the photons land, so photons have the equal probability going through each slit. To get the power $8^m = 2^{1000}$, we need 334 of qudits-2/8.

Qudits-2/10 system has Five double slit and 10 states. To get power $10^m = 2^{1000}$, we need 302 of qudits-2/10.

Qudits-2/12 system has Six double slit and 12 states. To get power $12^m = 2^{1000}$, we need 279 of qudits-2/12.

Qudits-2/16 system has Eight double slits and 16 states. To get power $16^m = 2^{1000}$, we need 250 of qudits-2/16.

Figure 4 shows how many Qudits formed by different number of the double slits are needed for reaching power of 2^{1000} .

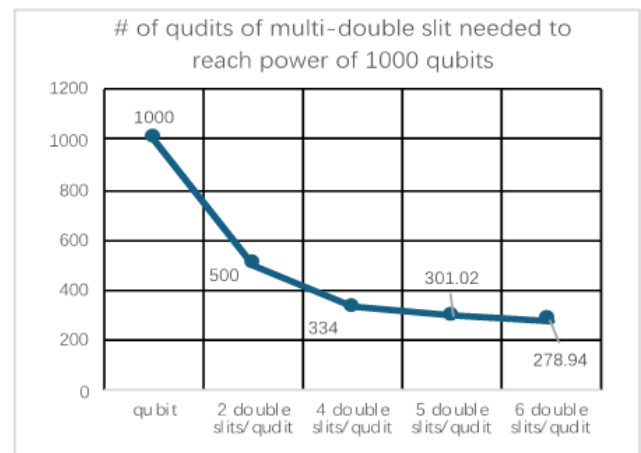


Figure 4. Qudits (multi-double slit) vs qubits

Qudits-2/8, Qudits-2/10, Qudits-2/12 and Qudits-2/16 can form Octal number system, Decimal number system, Duodecimal number system and Hexadecimal number system, respectively.

4. Qudits-3/y System

Now let us consider several examples of Qudits-3/y (Figure 5), formed by multi-triple-slits (multi-Qutrits).

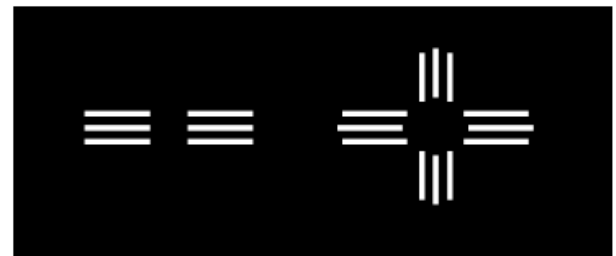


Figure 5. Qutrits of Multi-triple slits

Qutrits-3/6 system has two triple-slit and 6 states. To get power $(6)^m = 2^{1000}$, we need 387 qutrits-3/6.

Qudits-3/12 system has four triple-slits and 12 states. To get power $(12)^m = 2^{1000}$, we need 279 qudits-3/12.

Qudits-3/27 system has nine triple-slits and 27 states. To get power $(27)^m = 2^{1000}$, we need 211 qudits-3/27.

Figure 6 shows how many Qudits formed by

different number of the triple slits are needed for reaching power of 2^{1000} .

Qudits-3/12 can form Duodecimal number system.

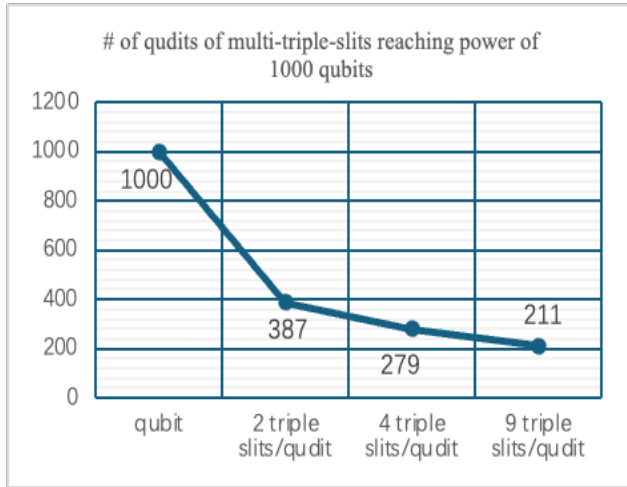


Figure 6. Qudits (multi-triple slits) vs qubits

5. Qudits-1-2-3/y System

Now let us consider two examples of Qudits-1-2-3/y, combination of single slit, double slits and triple slit (Figure 7).

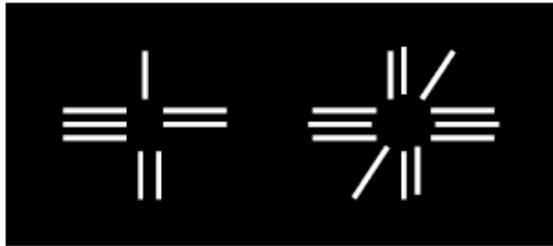


Figure 7. Combination of single slit, double slit and triple slits

Qudits-1-2-3/8 system has one single slit, two double slit and one triple slit and total 8 states. To get the power $8^m = 2^{1000}$, we need 334 of qudits-1-2-3/8.

Qudits-1-2-3/12 system has two single slits, two double slits and two triple slits and total 12 states. To get the power of $12^m = 2^{1000}$, we need 279 of qudits-1-2-3/12.

6. Summary

We show several examples of Qudits systems formed respectively by (1) multi-single-slits; (2) multi-double-slits; (3) multi-triple-slits; and (4) combination of single slit, double-slits, and triple-slits.

The above Qudits have higher dimensions that are multi-folds of that of the qubits.

The advantage of the so formed Qudits is to significantly reduce the number of Qudits needed for certain computation power (Figure 2, Figure 4, Figure 6, Figure 8).

Another advantage of the so formed Qudits is to be able to adopt the number systems other than the binary number system into quantum computing. Qudits-1/8, Qudits-2/8 and Qudits-1-2-3/8 can form Octal number system, respectively. Qudits-1/10 and Qudits-2/10 can form Decimal system, respectively. Qudits-1/12, Qudits-2/12, Qudits-3/12 and Qudits-1-2-3/12 can form Duodecimal number system, respectively. Qudits-1/16 and Qudits-2/16 can form Hexadecimal system, respectively.

The Qudits system can be modularized.

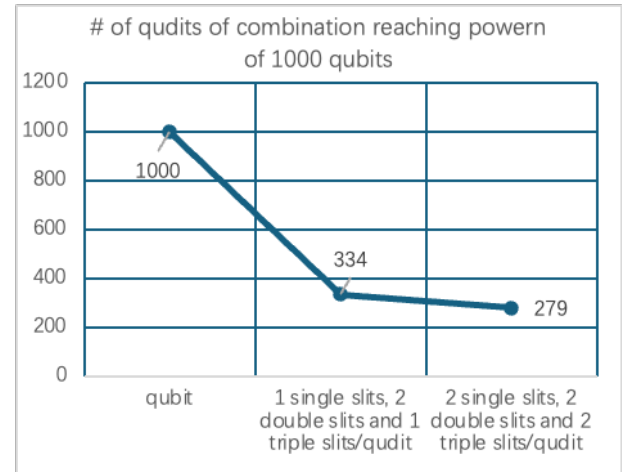


Figure 8. Qudits (combination) vs qubits

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