A new two-mode thermo- and squeezing-mixed optical field*

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We propose a new two-mode thermo- and squeezing-mixed optical field, described by the new density operator $\rho = \left(1-\mathrm{e}^{f}-|g|^2\right)\mathrm{e}^{ga^\dagger b^\dagger}\mathrm{e}^{fa^\dagger a}|0\rangle_{bb}\langle 0|\,\mathrm{e}^{g^* ab}$, where $|0\rangle_{bb}\langle 0|$ is the b-mode vacuum, $\mathrm{e}^{fa^\dagger a}$ represents the thermo-field, and $\mathrm{e}^{ga^\dagger b^\dagger}$ indicates squeezing. The photon statistics for ρ is studied by virtue of the method of integration within ordered product (IWOP) of operators. Such a field can be generated when a two-mode squeezed state passes through a one-mode dissipation channel.

Keywords: thermo- and squeezing-mixing, new optical field, photon statistics, integration within ordered product (IWOP) method

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1. Introduction

In recent years, quantum entanglement has attracted a great deal of interest of physicists.[1–4] A two-mode squeezed state is itself an entangled state of continuum variable and can be generated by a parametric amplifier.[5] Theoretically, the two-mode squeezed vacuum state is constructed by operating the squeezing operator[6]

$$S_2(\lambda) = \exp\left[\lambda\left(a^\dagger b^\dagger - ab\right)\right] \tag{1}$$

on the two-mode vacuum state, and the result is[7]

$$S_2(\lambda)|00\rangle = \mathrm{sech}\lambda\,\mathrm{e}^{a^\dagger b^\dagger \tanh\lambda}|00\rangle, \tag{2}$$

where $|00\rangle = |0\rangle_a|0\rangle_b$ and $\left[a,a^\dagger\right] = 1 = \left[b,b^\dagger\right]$. The corresponding density operator is

$$\begin{aligned} &S_2(\lambda)|00\rangle\langle 00|S_2^\dagger(\lambda) \\ &= \mathrm{sech}^2\lambda\,\mathrm{e}^{a^\dagger b^\dagger \tanh\lambda}|00\rangle\langle 00|\,\mathrm{e}^{ab\tanh\lambda} \equiv \rho_0, \end{aligned} \tag{3}$$

which is a pure state. Two interesting questions thus arise: 1) when one mode of the two-mode vacuum state is replaced by a thermo state, denoted by $\mathrm{e}^{fa^\dagger a}$, consequently, equation (3) is replaced by

$$\rho = C\mathrm{e}^{ga^\dagger b^\dagger}\left(\mathrm{e}^{fa^\dagger a}|0\rangle_{bb}\langle 0|\right)\mathrm{e}^{g^* ab}, \tag{4}$$

can this two-mode operator be qualified as a density operator (a mixed state), and how to determine the normalization constant C? 2) If the answer to the first question is affirmative, does this new density operator describe a real optical field? In other words, how can we generate such a photon field that is depicted by the density operator in Eq. (4)?

The purpose of this paper is to propose this kind of new thermo- and squeezing-mixed optical field described by Eq. (4). We shall reveal that it is physically realistic. In Section 2, we shall determine the normalization constant C to make up $\mathrm{Tr}\rho = 1$. In Sections 3 and 4, we perform partial trace over ρ to study the photon statistical properties of this new optical field by virtue of the method of integration within ordered product (IWOP) of operators.[8–11] In Section 5, we demonstrate that when a two-mode squeezed state ρ_0 passes through a one-mode dissipation channel, the resulting state just belongs to this type of thermo- and squeezing-mixed optical field, the one mode damping of the light field described by $\mathrm{sech}^2\lambda\,\mathrm{e}^{a^\dagger b^\dagger\tanh\lambda}|00\rangle\langle 00|\,\mathrm{e}^{ab\tanh\lambda}$ will affect the other mode, which exhibits quantum entanglement.

2. Evaluating the normalization constant C

By introducing the two-mode coherent state[12]

$$\begin{aligned} |z\rangle &= \exp\left[-\frac{|z|^2}{2}+za^\dagger\right]|0\rangle_a, \quad a|z\rangle = z|z\rangle, \\ |z'\rangle &= \exp\left[-\frac{|z'|^2}{2}+z'b^\dagger\right]|0\rangle_b, \quad b|z'\rangle = z'|z'\rangle \end{aligned} \tag{5}$$

with the completeness relation

$$\int\frac{\mathrm{d}^2z\mathrm{d}^2z'}{\pi^2}|z,z'\rangle\langle z,z'| = 1, \tag{6}$$

and using the normally ordered expansion of $\mathrm{e}^{fa^\dagger a}$

$$\mathrm{e}^{fa^\dagger a} =: \mathrm{e}^{\left(\mathrm{e}^f-1\right)a^\dagger a}:, \tag{7}$$

we calculate a trace for ρ in Eq. (4)

$$\mathrm{Tr}\rho = \mathrm{tr}_a\,\mathrm{tr}_b\,\rho$$

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$$
\begin{aligned}
&= C\mathrm{Tr}\left[\int \frac{\mathrm{d}^2z\mathrm{d}^2z'}{\pi^2}\left|z,z'\right\rangle\left\langle z,z'\right|\mathrm{e}^{ga^\dagger b^\dagger}\mathrm{e}^{fa^\dagger a}\left|0\right\rangle_{bb}\left\langle 0\right|\mathrm{e}^{g^*ab}\right]\\
&= C\int \frac{\mathrm{d}^2z\mathrm{d}^2z'}{\pi^2}\mathrm{e}^{gz^*z'^*}\left\langle z,z'\right|\mathrm{e}^{fa^\dagger a}\left|0\right\rangle_{bb}\left\langle 0\right|\mathrm{e}^{g^*zz'}\left|z,z'\right\rangle\\
&= C\int \frac{\mathrm{d}^2z\mathrm{d}^2z'}{\pi^2}\mathrm{e}^{-|z'|^2+gz^*z'^*+g^*zz'}\left\langle z\right|\mathrm{e}^{fa^\dagger a}\left|z\right\rangle\\
&= C\int \frac{\mathrm{d}^2z}{\pi}\mathrm{e}^{|gz-|^2}\left\langle z\right|:\mathrm{e}^{\left(\mathrm{e}^f-1\right)a^\dagger a}:\left|z\right\rangle\\
&= C\int \frac{\mathrm{d}^2z}{\pi}\mathrm{e}^{|gz|^2+\left(\mathrm{e}^f-1\right)|z|^2} = C\frac{1}{1-\mathrm{e}^f-|g|^2} = 1, \qquad (8)
\end{aligned}
$$

so

$$C = 1-\mathrm{e}^f-|g|^2, \qquad (9)$$

thus

$$\rho = \left(1-\mathrm{e}^f-|g|^2\right)\mathrm{e}^{ga^\dagger b^\dagger}\mathrm{e}^{fa^\dagger a}\left|0\right\rangle_{bb}\left\langle 0\right|\mathrm{e}^{g^*ab}, \qquad (10)$$

which is a new mixed state. Particularly, when $g=0$, $\rho\to\left(1-\mathrm{e}^f\right)\mathrm{e}^{fa^\dagger a}\left|0\right\rangle_{bb}\left\langle 0\right|$, which represents a thermo state in a-mode and a vacuum state in b-mode.

For instance, when

$$g = \tanh\sigma, \quad f = \ln\left(\mathrm{sech}^2\sigma\tanh^2\lambda\right), \qquad (11)$$

then

$$C = 1-\mathrm{sech}^2\sigma\tanh^2\lambda+\tanh^2\sigma = \mathrm{sech}^2\sigma\mathrm{sech}^2\lambda, \qquad (12)$$

and when

$$g = \mathrm{e}^{-\kappa t}\tanh\sigma, \quad f = \ln\left[\left(1-\mathrm{e}^{-2\kappa t}\right)\tanh^2\sigma\right], \qquad (13)$$

$$C = 1-\left(1-\mathrm{e}^{-2\kappa t}\right)\tanh^2\sigma-\mathrm{e}^{-2\kappa t}\tanh^2\sigma = \mathrm{sech}^2\sigma. \qquad (14)$$

3. The partial trace of ρ

To study the photon statistical properties of ρ, let us perform the partial trace over a-mode of ρ

$$
\begin{aligned}
\mathrm{tr}_a\rho &= \left(1-\mathrm{e}^f-|g|^2\right)\mathrm{tr}_a\\
&\quad\times\left[\int\frac{\mathrm{d}^2z}{\pi}\left|z\right\rangle_{aa}\left\langle z\right|\mathrm{e}^{ga^\dagger b^\dagger}\mathrm{e}^{fa^\dagger a}\left|0\right\rangle_{bb}\left\langle 0\right|\mathrm{e}^{g^*ab}\right]\\
&= \left(1-\mathrm{e}^f-|g|^2\right)\\
&\quad\times\int\frac{\mathrm{d}^2z}{\pi}{}_a\left\langle z\right|\mathrm{e}^{ga^\dagger b^\dagger}\mathrm{e}^{fa^\dagger a}\left|0\right\rangle_{bb}\left\langle 0\right|\mathrm{e}^{g^*ab}\left|z\right\rangle_a\\
&= \left(1-\mathrm{e}^f-|g|^2\right)\\
&\quad\times\int\frac{\mathrm{d}^2z}{\pi}{}_a\left\langle z\right|\mathrm{e}^{fa^\dagger a}\left|z\right\rangle_a\mathrm{e}^{gz^*b^\dagger}\left|0\right\rangle_{bb}\left\langle 0\right|\mathrm{e}^{g^*zb}. \qquad (15)
\end{aligned}
$$

By using the method of integration within ordered product (IWOP) of operators and

$$\left|0\right\rangle_{bb}\left\langle 0\right| =: \exp\left[-b^\dagger b\right]:, \qquad (16)$$

equation (15) is further turned into

$$
\begin{aligned}
\mathrm{tr}_a\rho &= \left(1-\mathrm{e}^f-|g|^2\right)\int\frac{\mathrm{d}^2z}{\pi}:\mathrm{e}^{\left(\mathrm{e}^f-1\right)|z|^2+gz^*b^\dagger+g^*zb-b^\dagger b}:\\
&= \frac{1-\mathrm{e}^f-|g|^2}{1-\mathrm{e}^f}:\exp\left[\left(\frac{|g|^2}{1-\mathrm{e}^f}-1\right)b^\dagger b\right]:\\
&= \frac{1-\mathrm{e}^f-|g|^2}{1-\mathrm{e}^f}\exp\left(b^\dagger b\ln\frac{|g|^2}{1-\mathrm{e}^f}\right), \qquad (17)
\end{aligned}
$$

which is a thermo-field in b-mode.

Then we perform the partial trace over b-mode of ρ, again using the IWOP method we have

$$
\begin{aligned}
\mathrm{tr}_b\rho &= \left(1-\mathrm{e}^f-|g|^2\right)\\
&\quad\times\int\frac{\mathrm{d}^2z}{\pi}{}_b\left\langle z\right|\mathrm{e}^{ga^\dagger b^\dagger}\mathrm{e}^{fa^\dagger a}\left|0\right\rangle_{bb}\left\langle 0\right|\mathrm{e}^{g^*ab}\left|z\right\rangle_b\\
&= \left(1-\mathrm{e}^f-|g|^2\right)\int\frac{\mathrm{d}^2z}{\pi}\mathrm{e}^{ga^\dagger z^*}\mathrm{e}^{fa^\dagger a}\mathrm{e}^{g^*az-|z|^2}\\
&= \left(1-\mathrm{e}^f-|g|^2\right)\int\frac{\mathrm{d}^2z}{\pi}:\mathrm{e}^{ga^\dagger z^*}\mathrm{e}^{\left(\mathrm{e}^f-1\right)a^\dagger a}\mathrm{e}^{g^*az-|z|^2}:\\
&= \left(1-\mathrm{e}^f-|g|^2\right):\mathrm{e}^{\left(|g|^2+\mathrm{e}^f-1\right)a^\dagger a}:\\
&= \left(1-\mathrm{e}^f-|g|^2\right)\exp\left[a^\dagger a\ln\left(|g|^2+\mathrm{e}^f\right)\right], \qquad (18)
\end{aligned}
$$

which is also a thermo-field but is different from Eq. (17) in parameter.

4. b-mode photon counting distribution for ρ

The quantum mechanical photon counting distribution formula was first derived by Kelley and Kleiner.[13] As shown in Ref. [12] that for the case of single radiation mode, the probability distribution $\mathfrak{p}(m,T)$ of registering m photoelectrons in time interval T is given by

$$\mathfrak{p}(m,T) = \mathrm{Tr}\left\{\rho:\frac{\left(\xi a^\dagger a\right)^m}{m!}\mathrm{e}^{-\xi a^\dagger a}:\right\}, \qquad (19)$$

where $\xi\propto T$ is called the quantum efficiency (a measure) of the detector, : : stands for normal ordering, and ρ is a single-mode density operator of the light field concerned. Now we evaluate the single-mode (say b-mode) photon counting distribution for ρ. Using

$$
\begin{aligned}
:\left(b^\dagger b\right)^m\mathrm{e}^{-\xi b^\dagger b}: &= b^{\dagger m}:\mathrm{e}^{(1-\xi-1)b^\dagger b}:b^m\\
&= b^{\dagger m}\mathrm{e}^{b^\dagger b\ln(1-\xi)}b^m \qquad (20)
\end{aligned}
$$

and Eq. (17), we have

$$
\begin{aligned}
&\mathrm{Tr}\left\{\rho:\frac{\left(\xi b^\dagger b\right)^m}{m!}\mathrm{e}^{-\xi b^\dagger b}:\right\}\\
&= \mathrm{tr}_b\left[:\frac{\left(\xi b^\dagger b\right)^m}{m!}\mathrm{e}^{-\xi b^\dagger b}:\mathrm{tr}_a\rho\right]\\
&= \frac{\xi^m}{m!}\frac{1-\mathrm{e}^f-|g|^2}{1-\mathrm{e}^f}\mathrm{tr}_b\left[b^{\dagger m}\mathrm{e}^{b^\dagger b\ln(1-\xi)}b^m\mathrm{e}^{b^\dagger b\ln\frac{|g|^2}{1-\mathrm{e}^f}}\right]\\
&= \frac{\xi^m}{m!}\frac{1-\mathrm{e}^f-|g|^2}{1-\mathrm{e}^f}\\
&\quad\times\mathrm{tr}_b\left[b^{\dagger m}\mathrm{e}^{b^\dagger b\ln(1-\xi)}\mathrm{e}^{b^\dagger b\ln\frac{|g|^2}{1-\mathrm{e}^f}}\mathrm{e}^{-b^\dagger b\ln\frac{|g|^2}{1-\mathrm{e}^f}}b^m\mathrm{e}^{b^\dagger b\ln\frac{|g|^2}{1-\mathrm{e}^f}}\right]
\end{aligned}
$$

$$
\begin{aligned}
&= \frac{\xi^m}{m!}\frac{1-\mathrm{e}^f-|g|^2}{1-\mathrm{e}^f}\left(\frac{|g|^2}{1-\mathrm{e}^f}\right)^m \\
&\quad \times \mathrm{tr}_b[b^{\dagger m}\mathrm{e}^{b^\dagger b\ln\frac{(1-\xi)|g|^2}{1-\mathrm{e}^f}}b^m] \\
&= \frac{\xi^m}{m!}\frac{1-\mathrm{e}^f-|g|^2}{1-\mathrm{e}^f}\left(\frac{|g|^2}{1-\mathrm{e}^f}\right)^m \\
&\quad \times \int \frac{\mathrm{d}^2 z}{\pi}{}_b\langle z|b^{\dagger m}:\mathrm{e}^{b^\dagger b\left[\frac{(1-\xi)|g|^2}{1-\mathrm{e}^f}-1\right]}:b^m|z\rangle_b \\
&= \frac{\xi^m}{m!}\left(\frac{|g|^2}{1-\mathrm{e}^f}\right)^m\frac{1-\mathrm{e}^f-|g|^2}{1-\mathrm{e}^f} \\
&\quad \times \int \frac{\mathrm{d}^2 z}{\pi}|z|^{2m}\mathrm{e}^{\left[\frac{(1-\xi)|g|^2}{1-\mathrm{e}^f}-1\right]|z|^2} \\
&= \frac{1}{m!}\frac{1-\mathrm{e}^f-|g|^2}{1-\mathrm{e}^f-(1-\xi)|g|^2}\left(\frac{\xi|g|^2}{1-\mathrm{e}^f-(1-\xi)|g|^2}\right)^m. \qquad (21)
\end{aligned}
$$

Then we consider the a-mode photon counting distribution. Using Eq. (18), we derive

$$
\begin{aligned}
&\mathrm{Tr}\left\{\rho:\frac{\left(\xi a^\dagger a\right)^m}{m!}\mathrm{e}^{-\xi a^\dagger a}:\right\} \\
&= \mathrm{tr}_a\left[:\frac{\left(\xi a^\dagger a\right)^m}{m!}\mathrm{e}^{-\xi a^\dagger a}:\mathrm{tr}_b\rho\right] \\
&= \frac{\xi^m}{m!}\left(1-\mathrm{e}^f-|g|^2\right)\mathrm{tr}_a[a^{\dagger m}\mathrm{e}^{a^\dagger a\ln(1-\xi)}a^m\mathrm{e}^{a^\dagger a\ln\left(|g|^2+\mathrm{e}^f\right)}] \\
&= \frac{\xi^m}{m!}\left(1-\mathrm{e}^f-|g|^2\right)\left(|g|^2+\mathrm{e}^f\right)^m \\
&\quad \times \mathrm{tr}_a[a^{\dagger m}\mathrm{e}^{a^\dagger a\ln\left[(1-\xi)\left(|g|^2+\mathrm{e}^f\right)\right]}a^m] \\
&= \frac{\xi^m}{m!}\left(1-\mathrm{e}^f-|g|^2\right)\left(|g|^2+\mathrm{e}^f\right)^m \\
&\quad \times \int \frac{\mathrm{d}^2 z}{\pi}{}_a\langle z|a^{\dagger m}:\mathrm{e}^{a^\dagger a\left[(1-\xi)\left(|g|^2+\mathrm{e}^f\right)-1\right]}:a^m|z\rangle_a \\
&= \frac{\xi^m}{m!}\left(1-\mathrm{e}^f-|g|^2\right)\left(|g|^2+\mathrm{e}^f\right)^m \\
&\quad \times \int \frac{\mathrm{d}^2 z}{\pi}|z|^{2m}\mathrm{e}^{\left[(1-\xi)\left(|g|^2+\mathrm{e}^f\right)-1\right]|z|^2} \\
&= \frac{\xi^m}{m!}\frac{1-\mathrm{e}^f-|g|^2}{1-(1-\xi)\left(|g|^2+\mathrm{e}^f\right)} \\
&\quad \times \left[\frac{|g|^2+\mathrm{e}^f}{1-(1-\xi)\left(|g|^2+\mathrm{e}^f\right)}\right]^m, \qquad (22)
\end{aligned}
$$

which differs from Eq. (21).

5. Generation of the new optical field

In nature, most systems are immersed in their environments; energy exchange between a system and its environment always happens, this brings the system's dissipation with quantum decoherence. In quantum optics and quantum statistics theory, the associated amplitude damping mechanism of the system in physical processes is governed by the following master equation:[14,15]

$$
\frac{\mathrm{d}\rho(t)}{\mathrm{d}t} = \kappa\left(2a\rho a^\dagger - a^\dagger a\rho - \rho a^\dagger a\right), \qquad (23)
$$

where ρ is the density operator of the system, and κ is the rate of decay. Such an equation can be conveniently solved by virtue of the entangled state representation,[16,17] and the result is in so-called Kraus form

$$
\rho(t) = \sum_{n=0}^{\infty}\frac{V^n}{n!}\mathrm{e}^{-\kappa t a^\dagger a}a^n\rho_0 a^{\dagger n}\mathrm{e}^{-\kappa t a^\dagger a}, \qquad (24)
$$

where ρ_0 is system's initial density operator and

$$
V \equiv 1-\mathrm{e}^{-2\kappa t}. \qquad (25)
$$

Now we consider a-mode (idler mode or signal mode) dissipation of the two-mode squeezed light, expressed by Eq. (3), passing through a one-mode quantum damping channel, and ask what is the output state. We substitute Eq. (3) into Eq. (24) and obtain

$$
\begin{aligned}
\rho(t) &= \mathrm{sech}^2\lambda\sum_{n=0}^{\infty}\frac{V^n}{n!}\mathrm{e}^{-\kappa t a^\dagger a}a^n\mathrm{e}^{a^\dagger b^\dagger\tanh\lambda}|00\rangle\langle 00| \\
&\quad \times \mathrm{e}^{ab\tanh\lambda}a^{\dagger n}\mathrm{e}^{-\kappa t a^\dagger a}, \qquad (26)
\end{aligned}
$$

where

$$
a^n\mathrm{e}^{a^\dagger b^\dagger\tanh\lambda}|00\rangle = \left(b^\dagger\tanh\lambda\right)^n\mathrm{e}^{a^\dagger b^\dagger\tanh\lambda}|00\rangle, \qquad (27)
$$

thus

$$
\begin{aligned}
\rho(t) &= \mathrm{sech}^2\lambda\sum_{n=0}^{\infty}\frac{V^n\tanh^{2n}\lambda}{n!}\mathrm{e}^{-\kappa t a^\dagger a}b^{\dagger n} \\
&\quad \times \mathrm{e}^{a^\dagger b^\dagger\tanh\lambda}|00\rangle\langle 00|\mathrm{e}^{ab\tanh\lambda}b^n\mathrm{e}^{-\kappa t a^\dagger a} \\
&= \mathrm{sech}^2\lambda\sum_{n=0}^{\infty}\frac{V^n\tanh^{2n}\lambda}{n!}b^{\dagger n} \\
&\quad \times \mathrm{e}^{\mathrm{e}^{-\kappa t}a^\dagger b^\dagger\tanh\lambda}|00\rangle\langle 00|\mathrm{e}^{\mathrm{e}^{-\kappa t}ab\tanh\lambda}b^n. \qquad (28)
\end{aligned}
$$

Then using

$$
|00\rangle\langle 00| =: \mathrm{e}^{-a^\dagger a-b^\dagger b}: \qquad (29)
$$

and the method of summation within the ordered product of an operator, we have

$$
\begin{aligned}
\rho(t) &= \mathrm{sech}^2\lambda\sum_{n=0}^{\infty}\frac{V^n\tanh^{2n}\lambda}{n!}:b^{\dagger n}b^n\mathrm{e}^{\mathrm{e}^{-\kappa t}a^\dagger b^\dagger\tanh\lambda}\mathrm{e}^{\mathrm{e}^{-\kappa t}ab\tanh\lambda-a^\dagger a-b^\dagger b}: \\
&= \mathrm{sech}^2\lambda:\exp[b^\dagger b\left(1-\mathrm{e}^{-2\kappa t}\right)\tanh^2\lambda\,\mathrm{e}^{-\kappa t}\tanh\lambda\left(a^\dagger b^\dagger+ab\right)-a^\dagger a-b^\dagger b]: \\
&= \mathrm{sech}^2\lambda\exp\left[\mathrm{e}^{-\kappa t}a^\dagger b^\dagger\tanh\lambda\right]|0\rangle_{aa}\langle 0|\exp\left\{b^\dagger b\ln\left[\left(1-\mathrm{e}^{-2\kappa t}\right)\tanh^2\lambda\right]\right\}\exp\left(\mathrm{e}^{-\kappa t}ab\tanh\lambda\right). \qquad (30)
\end{aligned}
$$

Comparing with the standard form of the new field in Eq. (10),

$$\rho = \left(1 - \mathrm{e}^{f} - |g|^2\right) \mathrm{e}^{g a^\dagger b^\dagger} |0\rangle_{aa} \langle 0| \mathrm{e}^{f b^\dagger b} \mathrm{e}^{g^* a b}, \tag{31}$$

we find

$$g = \mathrm{e}^{-\kappa t} \tanh\lambda, \quad f = \ln\left[\left(1 - \mathrm{e}^{-2\kappa t}\right) \tanh^2\lambda\right], \tag{32}$$

$$C = 1 - \left(1 - \mathrm{e}^{-2\kappa t}\right) \tanh^2\lambda - \mathrm{e}^{-2\kappa t} \tanh^2\lambda = \mathrm{sech}^2\lambda. \tag{33}$$

Thus equation (30) just represents the type of the thermo- and squeezing-mixed optical field.

6. Summary

We have proposed a new thermo- and squeezing-mixed optical field whose density operator is presented as $\rho = \left(1 - \mathrm{e}^{f} - |g|^2\right) \mathrm{e}^{g a^\dagger b^\dagger} \mathrm{e}^{f a^\dagger a} |0\rangle_{bb} \langle 0| \mathrm{e}^{g^* a b}$. Such a field can be generated when a two-mode squeezed state passes through a one-mode dissipation channel. Its photon statistics can be calculated with the aid of the IWOP method.

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