$\LaTeX\,2_\varepsilon$ Template

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$$u_p^l(r,\phi) \propto r^l L_p^l(2r^2/w^2) e^{-r^2/w^2}\, e^{-il\phi} \tag{1}$$

1. Low gain.

2. $$H \sim \int d^3\mathbf{r}\chi^{(2)}(\mathbf{r})E_p^{(+)}(\mathbf{r},t)E_s^{(-)}(\mathbf{r},t)E_i^{(-)}(\mathbf{r},t) + H.c.$$

3. $$H = i\hbar\Gamma \int d\mathbf{q}_s d\mathbf{q}_i F(\mathbf{q}_s,\mathbf{q}_i) a^\dagger_{\mathbf{q}_s} a^\dagger_{\mathbf{q}_i} + H.c.$$

4. $$F(\mathbf{q}_s,\mathbf{q}_i) = C\exp\big\{-\sigma^2\frac{(\mathbf{q}_s+\mathbf{q}_i)^2}{2}\big\}\mathrm{sinc}\Big(\frac{L(\mathbf{q}_s-\mathbf{q}_i)^2}{4k_p}\Big)\exp\big\{i\frac{L(\mathbf{q}_s-\mathbf{q}_i)^2}{4k_p}\big\}$$

5. $$|\psi\rangle = \exp\Big\{-\frac{i}{\hbar}\int_{-\infty}^{\infty} dt H(t)\Big\}|0\rangle \approx -\frac{i}{\hbar}\int_{-\infty}^{\infty} dt H|0\rangle$$

6. Shmidt decomposition

7. $$F(q_s,q_i,\phi_s-\phi_i) = \sum_n \chi_n(q_s,q_i)e^{in(\phi_s-\phi_i)}$$

8. $$\chi_n(q_s,q_i) = \sum_m \sqrt{\lambda_{mn}}\frac{u_{mn}(q_s)}{\sqrt{q_s}}\frac{v_{mn}(q_i)}{\sqrt{q_i}}$$

9.
$$F(\mathbf{q}_s, \mathbf{q}_i) = \sum_{m,n} \sqrt{\lambda_{mn}} \frac{u_{mn}(q_s)}{\sqrt{q_s}} \frac{v_{mn}(q_i)}{\sqrt{q_i}} e^{in(\phi_s - \phi_i)}$$

10. broadband modes and hign gain

11.
$$A^\dagger_{mn} = \int d\mathbf{q}_s \frac{u_{mn}(q_s)}{\sqrt{q_s}} e^{in\phi_s} a^\dagger_{\mathbf{q}_s}$$

12.
$$B^\dagger_{mn} = \int d\mathbf{q}_i \frac{v_{mn}(q_i)}{\sqrt{q_i}} e^{-in\phi_i} a^\dagger_{\mathbf{q}_i}$$

13.
$$H = i\hbar\Gamma \sum_{m,n} \sqrt{\lambda_{mn}} (A^\dagger_{mn} B^\dagger_{mn} - A_{mn} B_{mn})$$

14.
$$\frac{dA_{mn}}{dt} = \frac{i}{\hbar}[H, A_{mn}]$$

15.
$$A^{out}_{mn} = A^{in}_{mn} \cosh[G\sqrt{\lambda_{mn}}] + [B^{in}_{mn}]^\dagger \sinh[G\sqrt{\lambda_{mn}}]$$

16.
$$B^{out}_{mn} = B^{in}_{mn} \cosh[G\sqrt{\lambda_{mn}}] + [A^{in}_{mn}]^\dagger \sinh[G\sqrt{\lambda_{mn}}]$$

17.
$$\frac{da_{\mathbf{q}_{s,i}}}{dt} = \Gamma \sum_{m,n} \sqrt{\lambda_{mn}} \frac{u_{mn}(q_s)}{\sqrt{q_s}} [A^\dagger_{mn} e^{-in\phi_{s,i}} + B^\dagger_{mn} e^{in\phi_{s,i}}]$$

18.
$$\langle N_s(\mathbf{q}_s) \rangle = \sum_{m,n} \frac{|u_{mn}(q_s)|^2}{q_s} (\sinh[G\sqrt{\lambda_{mn}}])^2$$

19. three crystals

20.

$$F(\mathbf{q}_s,\mathbf{q}_i) = C\exp\Big\{-\sigma^2\frac{(\mathbf{q}_s+\mathbf{q}_i)^2}{2}\Big\}\mathrm{sinc}\Big(\frac{\Delta\widetilde{q}L}{2}\Big)$$
$$\times\Big(\exp\Big\{\frac{i\Delta\widetilde{q}L}{2}\Big\}+\exp\Big\{i(\Delta\widetilde{q}^{air}d_1+\frac{3}{2}\Delta\widetilde{q}L)\Big\}+\exp\Big\{i(\Delta\widetilde{q}^{air}(d_1+d_2)+\frac{5}{2}\Delta\widetilde{q}L)\Big\}\Big) \tag{2}$$

21.

$$\Delta\widetilde{q} = \frac{(\mathbf{q}_s-\mathbf{q}_i)^2}{2k_p}$$

22.

$$\Delta\widetilde{q}^{air} = \frac{(\mathbf{q}_s-\mathbf{q}_i)^2}{2k_p}n_s + \frac{2\delta n^{air}k_s}{n_s}$$

23. splitters

24.

$$|\psi_{in}\rangle = g(a_1^\dagger)|0\rangle = \sum_{n=0} g_n(a_1^\dagger)^n|0\rangle$$

25.

$$|\psi_{aux}\rangle = f(a_2^\dagger)|0\rangle = \sum_{n=0} f_n(a_2^\dagger)^n|0\rangle$$

26.

$$|\psi\rangle = |\psi_{in}\rangle\otimes|\psi_{aux}\rangle = \sum_{m,n}\alpha_{m,n}(a_1^\dagger)^m(a_2^\dagger)^n|0\rangle^{\otimes 2}$$

27. loseless BS

28.

$$\sum_{m,n}|\alpha_{m,n}|^2 = 1$$

29.

$$\sum_{m,n}|\alpha_{m,n}^{(2)}|^2 = 1$$

30.

$$r_j^2+t_j^2+a_j^2 = 1$$

31.
$$a_1^\dagger \to r_j a_1^\dagger + it_j a_2^\dagger$$

32.
$$a_2^\dagger \to r_j a_2^\dagger + it_j a_1^\dagger$$

33. state in area 2 after first BS

34.
$$|\psi_2\rangle = \sum_{m,n} \alpha_{m,n}^{(2)} (a_1^\dagger)^m (a_2^\dagger)^n |0\rangle^{\otimes 2}$$

35. 4 channels

36.
$$|\psi_3\rangle = \sum_{p_1,p_2,p_3,p_4} \beta_{p_1,p_2,p_3,p_4} (a_1^\dagger)^{p_1} (a_2^\dagger)^{p_2} (a_3^\dagger)^{p_3} (a_4^\dagger)^{p_4} |0\rangle^{\otimes 4}$$

37. First and only one ideal detector was clicked

38.
$$|\psi_4\rangle = \sum_{\substack{p_1,p_2,p_4 \\ p_1>0,p_3=0}} |\beta_{p_1,p_2,0,p_4} \sqrt{p_1!p_2!p_4!}|^2 |p_2, p_4\rangle$$

39. First and third detectors were clicked

40.
$$|\psi_4\rangle = \sum_{\substack{p_1,p_2,p_3,p_4 \\ p_1>0,p_3>0}} |\beta_{p_1,p_2,p_3,p_4} \sqrt{p_1!p_2!p_3!p_4!}|^2 |p_2, p_4\rangle$$

41. No detection

42.
$$|\psi_4\rangle = \sum_{\substack{p_2,p_4 \\ p_1=0,p_3=0}} |\beta_{0,p_2,0,p_4} \sqrt{p_2!p_4!}|^2 |p_2, p_4\rangle$$

43. final state

44.
$$|\psi_{out}\rangle = \sum_{m,n} \alpha_{m,n}^{out} (a_1^\dagger)^m (a_2^\dagger)^n |0\rangle^{\otimes 2}$$

45. example with two coherent states - alpha=1

46.
$$|\psi\rangle = |\alpha\rangle \otimes |\alpha\rangle, \quad \alpha = 1$$

47. two coherent after BS

48.
$$|\psi_2\rangle \approx e^{-1}(1+\frac{1+i}{\sqrt{2}}a_1^\dagger+\frac{1+i}{\sqrt{2}}a_2^\dagger+ia_1^\dagger a_2^\dagger+\frac{i}{2}(a_1^\dagger)^2+\frac{i}{2}(a_2^\dagger)^2+\frac{i-1}{2\sqrt{2}}a_1^\dagger(a_2^\dagger)^2+\frac{i-1}{2\sqrt{2}}(a_1^\dagger)^2a_2^\dagger+...)$$

49. auto correlation

$$Autocorr_s(q,q^{'}) = \langle N_s(q)N_s(q^{'})\rangle - \langle N_s(q)\rangle\langle N_s(q^{'})\rangle =$$
$$= \langle a_s^\dagger(q)a_s(q)a_s^\dagger(q^{'})a_s(q^{'})\rangle - \langle a_s^\dagger(q)a_s(q)\rangle\langle a_s^\dagger(q^{'})a_s(q^{'})\rangle$$

50. cross correlation

$$Crosscorr(q,q^{'}) = \langle N_s(q)N_i(q^{'})\rangle - \langle N_s(q)\rangle\langle N_i(q^{'})\rangle =$$
$$= \langle a_s^\dagger(q)a_s(q)a_i^\dagger(q^{'})a_i(q^{'})\rangle - \langle a_s^\dagger(q)a_s(q)\rangle\langle a_i^\dagger(q^{'})a_i(q^{'})\rangle$$

51. POVM operators

52.
$$\Pi_{no-click} = \sum_{n=0}^{\infty}(1-\eta_{SPD})^n|n\rangle\langle n|$$

53.
$$\Pi_{click} = 1 - \Pi_{no-click} = \sum_{n=0}^{\infty}[1-(1-\eta_{SPD})^n]|n\rangle\langle n|$$

54. After projection

55. Only first clicked

56.
$$|\psi_{out}\rangle = \Pi_{click}^{(1)}|\psi_{in}\rangle$$

57. Two clicked 1st and 3rd

58.
$$|\psi_{out}\rangle = \Pi^{(1)}_{click}\Pi^{(3)}_{click}|\psi_{in}\rangle$$

59. First and only one ideal detector was clicked

60.
$$|\psi_4\rangle = \sum_{\substack{p_1,p_2,p_4 \\ p_1\neq 0, p_3=0}} \beta_{p_1,p_2,0,p_4}\sqrt{p_1!}(b_2^\dagger)^{p_2}(b_4^\dagger)^{p_4}|0\rangle^{\otimes 2}$$

61. First and third detectors were clicked

62.
$$|\psi_4\rangle = \sum_{\substack{p_1,p_2,p_3,p_4 \\ p_1\neq 0, p_3\neq 0}} \beta_{p_1,p_2,p_3,p_4}\sqrt{p_1!p_3!}(b_2^\dagger)^{p_2}(b_4^\dagger)^{p_4}|0\rangle^{\otimes 2}$$

63. No detection

64.
$$|\psi_4\rangle = \sum_{\substack{p_2,p_4 \\ p_1=0, p_3=0}} \beta_{0,p_2,0,p_4}(b_2^\dagger)^{p_2}(b_4^\dagger)^{p_4}|0\rangle^{\otimes 2}$$

65. Projection operators

$$\begin{aligned}
\hat{\Pi} &= \Pi^{(1)}_{click} \otimes \mathrm{I}^{(2)} \otimes \Pi^{(3)}_{click} \otimes \mathrm{I}^{(4)} \\
\hat{\Pi} &= \Pi^{(1)}_{click} \otimes \mathrm{I}^{(2)} \otimes \Pi^{(3)}_{no-click} \otimes \mathrm{I}^{(4)} \\
\hat{\Pi} &= \Pi^{(1)}_{no-click} \otimes \mathrm{I}^{(2)} \otimes \Pi^{(3)}_{click} \otimes \mathrm{I}^{(4)} \\
\hat{\Pi} &= \Pi^{(1)}_{no-click} \otimes \mathrm{I}^{(2)} \otimes \Pi^{(3)}_{no-click} \otimes \mathrm{I}^{(4)}
\end{aligned}$$

66. state before detection

67.
$$|\psi_4\rangle = \sum_{p_1,p_2,p_3,p_4} \beta_{p_1,p_2,p_3,p_4}(b_1^\dagger)^{p_1}(b_2^\dagger)^{p_2}(b_3^\dagger)^{p_3}(b_4^\dagger)^{p_4}|0\rangle^{\otimes 4}$$

68. detection formulla

69.
$$\rho = Tr_{1,3}(\hat{\Pi}|\psi_{in}\rangle\langle\psi_{in}|\hat{\Pi}^\dagger)$$

70. dens matrix after detection

71.
$$\rho = \sum_{\substack{p_2,p_4\\p_2',p_4'}} \rho_{p_2,p_4,p_2',p_4'} |p_2\rangle\langle p_2'| \otimes |p_4\rangle\langle p_4'|$$

72. last BS:

73.
$$|p_2,p_4\rangle\langle p_2',p_4'| = \frac{1}{\sqrt{p_2!p_4!p_2'!p_4'!}}(a_2^\dagger)^{p_2}(a_4^\dagger)^{p_4}|0,0\rangle\langle 0,0|(a_2)^{p_2'}(a_4)^{p_4'}$$

74. dens matrix after detection

75.
$$\rho^{out} = \sum_{\substack{p_1,p_2\\p_1',p_2'}} \rho^{out}_{p_1,p_2,p_1',p_2'} |p_1\rangle\langle p_1'| \otimes |p_2\rangle\langle p_2'|$$

76. dens matrix of subsystem

77.
$$\rho_1 = Tr_2(\rho_{12})$$

78. Entanglemen Von neiman entropy

79.
$$S = 1$$