$$\int dy \, (\Phi^\dagger \Phi)^2 = \sum_{n_1, n_2, n_3, n_4} e^{-i(n_1 - n_2 + n_3 - n_4)y/R} \, \Phi^{(n_1)\dagger} \Phi^{(n_2)} \Phi^{(n_3)\dagger} \Phi^{(n_4)}$$