APPENDIX B

MULTI-PHOTON WAVE PACKETS

A superposition of nuclear wave packets comprises the electronic amplitude prepared in either a one-color or two-color nonlinear WPI experiment. Phase-cycling isolates the quadrilinear contributions to the subsequently detected population. In Chapters III and IV, we have stated the forms of those wave packets which depend on single-photon excitations and which, consequently, comprise the quadrilinear interference terms. For completeness, we include here explicit forms of the other wave packets that contribute to the prepared electronic amplitude and which depend on multi-photon transitions.

One-color Nonlinear WPI

In Chapter III, the following wave packets contribute to the excited electronic amplitude given by Eq. (3.26):

$$\left|(111)_f\right\rangle = e^{\ iH_f t_{41}} R_1^{fg} e^{iH_g t_{31}} \left|\ \ _g\right\rangle \tag{B.1}$$

$$\left|(222)_f\right\rangle = e^{\ iH_f t_{42}} R_2^{fg} e^{iH_g t_{32}} \left|\ \ _g\right\rangle \tag{B.2}$$

$$\left|(333)_f\right\rangle = e^{\ iH_f t_{43}} R_3^{fg} \left|\ \ _g\right\rangle \tag{B.3}$$

$$\left|(444)_f\right\rangle = R_4^{fg} e^{\ iH_g t_{43}} \left|\ \ _g\right\rangle \tag{B.4}$$

$$\left|(211)_f\right\rangle = e^{\ iH_f t_{42}} P_2^{fg} e^{\ iH_g t_{21}} Q_1^{fg} e^{iH_g t_{31}} \left|\ \ _g\right\rangle \tag{B.5}$$

$$\left|(311)_f\right\rangle = e^{\ iH_f t_{43}} P_3^{fg} e^{\ iH_g t_{31}} Q_1^{fg} e^{iH_g t_{31}} \left|\ \ _g\right\rangle \tag{B.6}$$

$$\left|(411)_f\right\rangle = P_4^{fg} e^{\ iH_g t_{41}} Q_1^{fg} e^{iH_g t_{31}} \left|\ \ _g\right\rangle \tag{B.7}$$

$$\left|(221)_f\right\rangle = e^{\ iH_f t_{42}} Q_2^{gf} e^{\ iH_f t_{21}} P_1^{fg} e^{iH_g t_{31}} \left|\ \ _g\right\rangle \tag{B.8}$$

$$\left|(322)_f\right\rangle = e^{\ iH_f t_{43}} P_3^{fg} e^{\ iH_g t_{32}} Q_2^{fg} e^{iH_g t_{32}} \left|\ \ _g\right\rangle \tag{B.9}$$

$$\left|(422)_f\right\rangle = P_4^{fg} e^{\ iH_g t_{42}} Q_2^{fg} e^{iH_g t_{32}} \left|\ \ _g\right\rangle \tag{B.10}$$

$$\left|(331)_f\right\rangle = e^{\ iH_f t_{43}} Q_3^{gf} e^{\ iH_f t_{31}} P_1^{fg} e^{iH_g t_{31}} \left|\ \ _g\right\rangle \tag{B.11}$$

$$\left|(332)_f\right\rangle = e^{\ iH_f t_{43}} Q_3^{gf} e^{\ iH_f t_{32}} P_2^{fg} e^{iH_g t_{32}} \left|\ \ _g\right\rangle \tag{B.12}$$

$$\left|(422)_f\right\rangle = P_4^{fg} e^{\ iH_g t_{43}} Q_3^{fg} \left|\ \ _g\right\rangle \tag{B.13}$$

$$\left|(441)_f\right\rangle = Q_4^{gf} e^{\ iH_f t_{41}} P_1^{fg} e^{iH_g t_{31}} \left|\ \ _g\right\rangle \tag{B.14}$$

$$\left|(442)_f\right\rangle = Q_4^{gf} e^{\ iH_f t_{42}} P_2^{fg} e^{iH_g t_{32}} \left|\ \ _g\right\rangle \tag{B.15}$$

$$\left|(443)_f\right\rangle = Q_4^{gf} e^{\ iH_f t_{43}} P_3^{fg} e^{iH_g t_{32}} \left|\ \ _g\right\rangle \tag{B.16}$$

where the one-, two-, and three-photon pulse propagators, P_j^{fg}, Q_j^{fg}, and R_j^{fg}, are given by Eqs. (3.17), (3.23), and (3.21), respectively.

Two-color Nonlinear WPI

In Chapter IV, the following wave packets contribute to the excited electronic amplitude given by Eq. (4.30):

$$\left|(333)_f\right\rangle = e^{iH_f t_{43}} R_3^{fg} \left|\ \ _g\right\rangle \tag{B.17}$$

$$\left|(433)_f\right\rangle = P_4^{fg} e^{iH_g t_{43}} Q_3^{eg} \left|\ \ _g\right\rangle \tag{B.18}$$

$$\left|(443)_f\right\rangle = Q_4^{gf} e^{iH_f t_{43}} P_3^{fg} \left|\ \ _g\right\rangle \tag{B.19}$$

$$\left|(444)_f\right\rangle = R_4^{fg} e^{iH_g t_{43}} \left|\ \ _g\right\rangle \tag{B.20}$$

$$\left|(311)_f\right\rangle = e^{iH_f t_{43}} P_3^{fg} e^{iH_g t_{31}} Q_1^{eg} e^{iH_g t_{31}} \left|\ \ _g\right\rangle \tag{B.21}$$

$$\left|(322)_f\right\rangle = e^{iH_f t_{43}} P_3^{fg} e^{iH_g t_{32}} Q_2^{eg} e^{iH_g t_{32}} \left|\ \ _g\right\rangle \tag{B.22}$$

$$\left|(411)_f\right\rangle = P_4^{fg} e^{iH_g t_{41}} Q_1^{eg} e^{iH_g t_{31}} \left|\ \ _g\right\rangle \tag{B.23}$$

$$\left|(422)_f\right\rangle = P_4^{fg} e^{iH_g t_{42}} Q_2^{eg} e^{iH_g t_{32}} \left|\ \ _g\right\rangle \tag{B.24}$$

where the one-, two-, and three-photon $f \quad g$ pulse propagators, P_j^{fg}, Q_j^{fg}, and R_j^{fg}, are given by Eqs. (4.17), (4.22), and (4.19), respectively. Analogous expressions exist for the $e \quad g$ pulse propagator P_j^{eg} and Q_j^{eg}.