

光电工程

Opto-Electronic Engineering

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Scopus CSCD

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G I 1DQRSDUWLFOH VHOI DVVHPEO\> i @ 6FDOH EDU H QP I QP)LJXUH UHSURGX
&KHPLFDO 6RFLHW\ E UHI > @ H UHI > @ DQG I UHI > @ < XQGHU D &UHDWLYH &RF
,QWHUQDWLRQDO /LFHQVH F UHI > @ < \$PHULFDQ &KHPLFDO 6RFLHW\ G UHI > @ < 7K

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RI SRO\PHU VLOYHU PLFURSLOODUV> @ F 6HOI DVVHPEO\ RI SRO\PHU VLOYHU PLFURSL
H 6HOI DVVHPEO\ RI SRO\PHU JROG PLFURSLOODUV> @)LJXUH UHSURGXFHG ZLWK SHUPL
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 E 7KUHH GLPHQVLRQDO 6(56 VWUXFWXUH EDVHG RQ FDSLOODU\ IRUFH VHOI D
)LJXUH UHSURGXFHG ZLWK SHUPLVVLRQ IURP D UHI > @ < \$PHULFDQ &KHPLFD

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5DPDQ VFDWWHULQJ PDSSLQJ RQ ' SODVPRQLF íQDQRSLOODU
 DUUD\>-@ 6PDOO > @6WLOHV 3 / 'LHULQJHU - \$ 6KDK 1 & HW DO
 > @/LX < *XDQJ - < /LX & HW DO 6LPSOH 5DPDQ VSHFWURVFRS\>-@ \$QQX 5HY \$QDO
 SODVPRQLF ILEHUý RSWLF SUREH DV 6(56 DQG ELRVHQVLQJ
 SODWIRUP>-@ \$GY 2SW 0DWHU > @'LQJ 6 < <RX (0 7LDQ = 4 HW DO (OHFWUR
 > @0RJHUD 8 *XR + 1DPNRRQJ 0 HW DO :HDURXU 5DPDQ VSHFWURVFRS\>-@ \$QQX 5HY \$QDO
 SDSHU±EDVHG PLFURIOXLGLFV IRU FRQWLQXR XV VZHDWíDQDO\VLV>-@
 6FL \$GY HDEQ > @3KDQ 4XDQJ * & /HH + . 3KDQJ , < HW DO
 > @0D = & =KDQJ < / +DQ % HW DO)HPWRVHFRQRQRVFRS\>-@ \$QQX 5HY \$QDO
 ZULWLQJ RI PHWDOOLF PLFUR QDQRVWUXHFKDQVHGURRUIDEHLFDMRIRU PXOWLSKDVH
 VWUDWHJLHV WR IXWXUH DSSOLFDWLRQV>@0HFWURQ &KHP , QW (G
 > @6XJLRND . &KHQJ < 8OWUDIDVW ODVHUVHFRQRQRVFRS\>-@ \$QQX 5HY \$QDO
 DGYDQFHG PDWHULDOV SURFHVVLQJ>-@ /LHULQJHU &KHP 6RF 5HY
 H > @,P + %DQW] . & /HH 6 + HW DO 6HOI DVVHPEO
 > @:X ' ;X - 1LX / * HW DO ,Q FDKQHO 5DPDQ VSHFWURVFRS\>-@ \$QQX 5HY \$QDO
 GHVLJQDEOH PLFURRSWLFDO GHYLFHV XVLQJ \$GYDQFHG IIRROG VXSSRUWHG
 IHPWRVHFRQG ODVHU PLFURIDEULFDWLRQ:KLJKH \$RQVFRS\>-@ \$QQX 5HY \$QDO
 RSWRIOXLGLF FHOO FRXQWLQJ>-@ /LJKW 6RF 5HY \$QDO
 > @.DZDWD 6 6XQ + % 7DQDND 7 HW DO)LHULQJHU &KHP 6RF 5HY \$QDO
 IXQFWLRQDO PLFURGHYLFHV>-@ 1DWXUH &KHP % í í
 > @=KRX : 3 %DL 6 ;LH = : HW DO 5HVHDUFK SURRUIHFRQRQRVFRS\>-@ \$QQX 5HY \$QDO
 GLUHFV ZULWLQJ IDEULFDWLRQ RI PHWDOOLF QDQRVWUXHFKDQVHGURRUIDEHLFDMRIRU
 VWUXFWXUHV DQG GHYLFHV>-@ 2SWR (OHFWURQ &KHP , QW (G
 PDWHULDOV DQG RUJDQLF KHWHURVWUXFW
 "Kÿ +@- AN,' Ou \$i u, Å b3Fy Š :-ß | Å Ú 3ÿ ° > @<DQJ ; ,OHUL 1 /DUVRQ & & HW DO 1DQRS
 :"-@/E •>-@ u*a /7 > @<DQJ ; ,OHUL 1 /DUVRQ & & HW DO 1DQRS
 > @/LDR - 1 =KDQJ ' 6 /L = * \$GYDQFH LQ IHPWRVHFRQG ODVHU VFDWWHULQJ>-@ \$QQX 5HY \$QDO
 IDEULFDWLRQ RI IOH[LEOH HOHFWRQLFV>-@ 2SWR (OHFWURQ &KHP , QW (G
 > @/LQ ' ' :X = / /L 6 - HW DO /DUJH DUHD DX
 5- LH- zJ\$) N.p\$ub3 S*a|"E •>-@ IXQFWLRQDOLJHG 6L QDQRURG DUUD\>@ \$& 1DQR
 u*a /7 HQKDQFHG 5DPDQ VSHFWURVFRS\>-@ \$& 1DQR
 > @/XR ; 3DQ 5 &DL 0 < HW DO \$WWR 0RODU 5DPDQ GHWHFWLRQ RQ
 SDWWHUQHG VXSHUK\GURSKLOLF VXSHUK\GURSKLOLF SODWIRUPDQD 4 HW DO \$ JH
 ORFDOL]DEOH HYDSRUDWLRQ HQULFKPHQWPHWKRGORJFRXQWLQJ>-@ \$QQX 5HY \$QDO
 &KHP GHWHFWLRQ OLPLW DQG XQLRUPLW\ E\ PD[L
 > @:X / 0 /LX + * =KRX + HW DO 2QH VWHS IDEULFDWLRQ \$GFHWDO:HLQK
 QDQRSDUWLFOHV RQ SRO\PHU ILOP E\ IHPWRVHFRQG:K\$<PHWKRGYDQ ' ' HW DO 3OD
 IRU 6(56 GHWHFWLRQ>-@ 7DODQWD 1DQRKROH DUUD\ IRU VXUIDFH HQKDQFHG
 > @:X % % 0D = & :DQJ / HW DO /RFDOLJHG IDEULFDWLRQRI PHWDOOLF QDQRVWUXHFKDQVHGURRUIDEHLFDMRIRU
 RI KLJK HILFLHQF\ VXUIDFH HQKDQFHG 5DPDQ VFDWWHULQJ 6(56
 PRQLWRUV LQWR PLFURIOXLGLF FDKQHO\NHO 7/DE &KLS 7LDQ & HW DO &HOOXODU
 í DVVHPEO\ RI KRW VSRW 6(56 DQG SKRWRDFR
 > @/DQJHU - 'H \$EHUDVWXUL ' - \$LJSXUD - HWLOO 3ULWHQX DQK
 IXWXUH RI VXUIDFH HQKDQFHG 5DPDQ VFDWWHULQJ>-@ \$& 1DQR
 í > @7LDQ / 6X 0 . <X) HW DO /LTXLG VWDWH
 > @)OHLVFKPDQQ 0 +HQGUD 3 - 0F4XLOODQ \$DQSDQ RSHFRQDRUGHUHG PHWDO OLTXLG
 RI S\ULGLQH DGVRUEHG DW D VLOYHU HOHFWRQLFV>-@ \$QQX 5HY \$QDO
 í > @)DQ - \$:X & %DR . HW DO 6HOI DVVHPEO
 > @-HDQPDLUH ' / 9DQ 'X\QH 5 3 6XUIDFDQSDUWLFOH &OXVWHUV>-@ 6FLHQFH
 VSHFWURHOHFWRURFKHPLVWU\ 3DUW , +HWUÍR\FOLF DURPDWLF DQG
 DOLSKDWLF DPLQHV DGVRUEHG RQ >HWLOO 3ULWHQX DQK
 HOHFWRURGH>-@ - (OHFWURDQD &KHP , QW (G
 í VSHFWURVFRS\>-@ \$& 1DQR í
 > @/HH + . /HH < + .RK & 6 / HW DO 'HVLQDQJ) VXUÍRQLRW 3 .ULVKDQ 6 HW DO 1D
 HQKDQFHG 5DPDQ VFDWWHULQJ 6(56 SODWIRUPVIRUEHFRQRQRVFRS\>-@ \$QQX 5HY \$QDO
 KRWVSRW HQJLQHULQJ HPHUJLQJ RSSRDXUÍRQLRW 3 .ULVKDQ 6 HW DO 1D
 PDQLSXODWLRQV DQG K\EULG PDWHULDOV>-@ &KHP 6RF 5HY

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> @'RQJ = + /LX < 4LQ < < HW DO )DEULFDWLRQ RI VLOYHU QDQRVWUXFWXUHV IURP DTXHRX
SUREHV E\ ODVHU LQGXFHG VHOI DVVHPEO@5DQ 3 -LDQJ / /L ; HW DO )HPWRVHFRQG
DQG LWV DSSOLFDWLRQV LQ WUDFH GHWHFWLRQ RI VLOYHU QDQRVWUXFWXUHV IURP DTXHRX
&KLQ - /DVHUV i DSSOLFDWLRQ LQ WLWVXH HQLLQHULQJ DQG
9•|A- D€ /))\ Ou $i uA ("bLZ7 3d=ñ" b3 u3D - $SSO %LRPDWHU )XQFW ODWHU
6(56Î' ö ç È·i"w Â*T>-@ Y)$i u > @5DQ 3 -LDQJ / /L ; HW DO )HPWRVHFRQG
i SODVPD HQKDQFHV SKRWRV\QWKHVLV F
> @/L & + 0D = & +X ; < HW DO 3UHSUDWLRQ RI VLOYHU QDQRVWUXFWXUHV IURP DTXHRX
PLFURIOXLGLF 5DPDQ GHWHFWLRQ FKLS>-@ &KLQ - /DVHUV
> @;X % % ;LD + 1LX / * HW DO )OH[LEOH QDQR
zQB— O•" 6A³ Ou Úm Óö(i"w7U's+°b3:Â*T QRQSODQDU VXEVWUDWHV E\ IHPWRVHF
>-@ Y)$i u HOHFWUROHVV SODWLQJ>-@ 6PDOO
> @+X 0 2X ) 6 :X : HW DO *ROG QDQRVWUXFWXUHV IURP DTXHRX
WUDSSLQJ DQG GHWHFWLRQ>-@ - $P &KHP &RPPXQ
i VLWX 6(56 PRQLWRULQJ>-@ &KHP &RPPXQ
> @/LX ) ; 6RQJ % ; 6X * ; HW DO 0ROHFXOH VHQLVQJ i VFXOSWLQJ
H[WUHPH HOHFWURPDJQHWLF ILHOG HQKDQFHV IURP DTXHRX IURP DTXHRX
PROHFXOH VHQLVQJ>-@ 6PDOO ZULWLQJ RI SODVPRQLF $J 3G DOOR\ QDQR
> @3DUN 6 * 0XQ & ;LDR ; ) HW DO 6XUIDFH IURP DTXHRX IURP DTXHRX
6(56 VXEVWUDWHV IRU PROHFXODU FRQFHQWUDWLRQ DW SODVPRQLF
QDQRJDSV>-@ $GY )XQFW ODWHU > @<DQ : - <DQJ / . &KHQ - 1 HW DO ,Q VL
> @=KX &+ 0HQJ * : =KHQJ 3 HW DO $ KLHUDWLRQ RI VLOYHU QDQRVWUXFWXUHV IURP DTXHRX
DUUD\ RI VLOYHU QDQRURG EXQGOHV IRU VXSHFWURVWUXFWXUHV IURP DTXHRX
VFDWWHULQJ GHWHFWLRQ RI SKHQROLF SROOXWDQWV>-@ $GY ODWHU
i > @/XR = - =HQJ = + /LX = < HW DO &OXVWHU
> @6RQJ % ; -LDQJ = + /LX = 5 HW DO 3URELQ IURP DTXHRX IURP DTXHRX
RI VWURQJ IOXRUVFHQFH HQKDQFHPHQW IURP DTXHRX IURP DTXHRX
ZLWK VXE QDQRPHWHU SUHFLVLRQ>-@ >$%DLQ 6HULHQ ' +X $ 0 HW DO ' PLFURI
i HQKDQFHG 5DPDQ VSHFWURVFRS\ 6(56 FKLS
> @:X . < /L 7 6FKPLGW 0 6 HW DO *ROG QDQRVWUXFWXUHV IURP DTXHRX
RQ UHF\FODEOH QDQRKRRGRRV HQLLQHULQJ IURP DTXHRX IURP DTXHRX
HQKDQFHG 5DPDQ VSHFWURVFRS\>-@ $G@QD5.HQLLQWHU&KL + 1 9DUPD 0 HW DO )HPW
IDEULFDWLRQ RI VLOYHU QDQRVWUXFWXUHV
> @0DFLDV 0RQWHUR 0 3HOi] 5 - 5LFR 9 -HQKDQFHG 5DPDQ VSHFWURVFRS\>-@ 6FL 5
WUHDWPHQW RI $J#=#Q2 QDQRURGV DV ORQJ OLIH VSDQ 6(56
VXUIDFHV>-@ $&6 $SSO ODWHU ,QWHU@HQJ < ) <LQ = 7DQ ; / HW DO )HPWRVHFRQ
i SRO\PHU 6(56 ILEHU SUREH ZLWK SKRWRUH
> @:X . & <DQ + 3 7DQ & ) HW DO +HGJHKRYLQVHU QDQRVWUXFWXUHV IURP DTXHRX
QDQRZLUHV &X2 FRPSRVLWHV IRU EURD@EDG:YH\LEOH OLRW / 1 HW DO )HPWRVH
GULYHQ UHF\FODEOH VXUIDFH HQKDQFHG 5DPDQ VSHFWURVFRS\>-@ ILEHU WDSHU 6(56 SUR
2SW ODWHU VLOYHU QDQRVWUXFWXUHV>-@ - 3KIV ' $SSO
> @*XUEDWRY 6 2 0RGLQ ( 3X]LNRY 9 HW DO %ODFN $X GHFRUDWHG
7L2 SURGXFHG YLD ODVHU DEODWLRQ RI VLOYHU QDQRVWUXFWXUHV IURP DTXHRX
,QWHUIDFHV i QDQR PLFURVWUXFWXULQJ DQG LWV DSSOLF
> @0RPPD & &KLFKNRY % 1 1ROWH 6 HW DO 5KRUW SXOV ODVHU
DEODWLRQ RI VROLG WDUJHWV>-@ 2SW @RPPD * / 2EVHUYDWLRQ RI QRQTXLOLEULX
i FRSSHU>-@ 3KIV 5HY /HWW i
> @*DWWDVV 5 5 0D]XU ( )HPWRVHFRQG ODVHU IURP DTXHRX IURP DTXHRX
WUDQVSDUHQW PDWHULDOV>-@ 1DW 3KRWRQ IURP DTXHRX IURP DTXHRX
> @.SHU 6 6WXNH 0 $EODWLRQ RI XY WUDQVSDUHQW IURP DTXHRX IURP DTXHRX
IHPWRVHFRQG XY H[FLPHU ODVHU SXOVHV>-@ i 0LFURHOHFWRUQ (QJ
i > @OVDHG $OL + ( 1RUULV 7 % 3HVVRW 0 $ HW
> @.SHU 6 6WXNH 0 $EODWLRQ RI SRO\WHWURVWUXFWXUHV IURP DTXHRX IURP DTXHRX
ZLWK IHPWRVHFRQG 89 H[FLPHU ODVHU SXOVHV>-@ ILEHU WDSHU 3KIV /HWW
i > @2JXUL . 2NDQR < 1LVKLNZD 7 HW DO
> @/LP 7 : 6RQ < -HRQJ < - HW DO 7KUHH IURP DTXHRX IURP DTXHRX
FURVVLQJ PDQLIROG PLFUR PL[HU IRU IDVHU IURP DTXHRX IURP DTXHRX
FURVVLQJ>-@ 3

```

ODVHU QDQRVWUXFWXUHG VXEVWUDWHV>-@
> @*ORYHU 7 (\$FNHUPDQ * ' /HH 5 : HW DO 0HWDO#LQVXODWRU
WUDQVLWLRQV LQ DQ H[SDQGLQJ PHWDOOL#LQVXODWRU <SDJWLFOH ;IRH#DQ#RZR VWHS IHP
GXULQJ IHPWRVHFRQG ODVHU DEODWLRQ>S@OV#HKWU#DUQVIDEULFDWLRQ RI QDQRVWUXFW
± í VXUIDFH HQKDQFHG 5DPDQ VFDWWHULQJ>-@
> @\$PRUXVR 6 %UX]]HVH 5 9LWLHOOR 0 HW DO ([SHULPHQWDO DQG
WKHRUHWLFDQ LQYHVWLJDWLRQV RI IHPW#DQ#FRQG /DQV;HU #DEODWH#WQD#I 6XUIDFH HQK
DOXPLQXP LQ YDFXXP>-@ - \$SSO 3K\V VFDWWHULQJ VLOLFQ VXEVWUDWH IDVW IDE
> @2JXUL . 2NDQR < 1LVKLNZD 7 HW DO 'QDPL#DQ#VW#HG#>@I \$SSO 3K\V \$
IHPWRVHFRQG ODVHU DEODWHG OLTXL#G DQ#PL#Q#G#V #DQ#D#B#MLF#X#R#G#D#]#W#i - HW DO
XVLQJ VSDWLRWHPSRUDOO\ UHVROYHG [G#H#H#E#P#R#H#S#W#K#H#Q#D#F#M#Q#D#O VXUIDFH DUHD RI
VWUXFWXUH VSHFWURVFRS\>-@ 3K\V 5HYV#H#V#R#U>-@ \$SSO 3K\V \$ í
> @OHNQDYLP#LHQ#i , 3DEU#i#ãD (7DODLNLV 0 HW
> @\$PRUXVR 6 %UX]]HVH 5 :DQJ ; HW DO)H#P#R#V#H#F#R#Q#G ODVHU#D#W#X#L#Q#J ODVHU DEODW
DEODWLRQ RI QLFNHO LQ YDFXXP>-@ - 3K\QD#R#V#W#X#U#H>-@ \$SSO 6XUI 6FL
í > @%RWD 5 (LDPFKDL 3 +RUSUDWKXP 0 HW
> @=DYHVWRYVND\D , 1 .DQDYLQ \$ 3 0HQD#P#H#D#H#Q#J#S#DY#H#V GHFRUDWHG ZLWK JROG QD
&U\#V#W#D#O#L#D#W#L#R#Q RI PHWDOV XQGHU FRQ#G#I#R#L#S#O#V#R#T#X#D#S#H#H#D#E#W#F#E#R#O#G#E#W#H#F#W#L#R#Q LQ
ZKHQ PDWHULDOV DUH SURFHVVHG ZLWK X#S#W#D#D#K#R#U#&#I#D#P#H#U SXOVHV>-@
- 2SW 7HFKQRO í > @L = + X - -LDQJ / HW DO 6KDSHG IHPW
> @+LVH\ & / 0LW[HOHQD ,ULEDUHQ 2 0DUW#t#Q#H#J#X#D#D#H#G#y#G#H#S#R#H#W#D#L#R#Q VLWHV RI JDOYDQL
\$ YHUV#D#W#L#O#H FDQFHU FHOO WUDSSLQJ DQ#S#U#H#S#D#W#D#W#L#R#Q #R#V#D#D#L#Q#H#D#U#D#H FRQWURO
PLFURIOXLGLF GHYLFH>-@ %LR#P#L#F#U#R#I#O#X#L#G#D#D#R#S#D#U#W#L#F#O#H#V>-@ \$SSO 6XUI 6FL
> @&KDQJ + : 7VDL < & &KHQJ & : HW DO>1D#Q#R#V#W#U#X#F#W#X#U#H#G \$#K#X#D 7 & HW DO)DEULFDV
VXUIDFH IDEULFDWHG E\ IHPWRVHFRQG 0#D#F#H#W#U#D#R#U#H#V#V#E#I#D#F#H#P#R#V#H#F#R#Q#G /,3\$\$ IRU
HQKDQFHG 5DPDQ VFDWWHULQJ>-@ - &R#O#R#R#Q#W#D#P#H#D#D#Q#W#V#6#F#L IRRGV>-@ 2SW /DVHU 7
í
> @/XR ; % /LX : - &KHQJ & + HW DO)HP#R#V#H#F#R#Q#G 0#D#V#B#Q #L#F#L#H#Q#J - * HW DO \$ VLPSOH
1DQR VWUXFWXUH \$J 6(56 VXEVWUDWHV Z#D#W#K#L#X#Q#L#H#G#H#P#W#R#G#W#I#R#L#W#D#E#U#L#F#D#W#L#R#Q RI VX
XQLR#U#P#L#W\ DQG VWDELOLW\ IRU IRRG V#D#H#W#H#U#D#D#K#R#L#W#G#>@Q 150P>-@ 1DQR#V#F#D#O
/DVHU 7HFKQRO
> @/X / % =KDQJ - 5 -LDR / 6 HW DO /DU#H#E#F#D#H#D#E#U#L#F#D#D#R#Q#R#I#H#W DO ([WUH#P#H#O\ V#H
QDQRVWUXFWXUH RQ ELR PHWDOOLF VXEVW#H#D#W#H#R#U#E#D#V#H#G#H#Q#K#D#D#F#H#G#P#R#V#H#F#R#Q#G O
5DPDQ DQG IOXR#U#H#V#F#H#Q#F#H VFDWWHULQJ#X#S#H#U#K#I#G#R#S#K#R#E#U#E#D#S#K#L#O#L#F#P#L#F#U#R#S#R#X#V#S
%DVHO í
> @=KDQJ : ' /L & *DR . HW DO 6XUIDFH#H#Q#K#D#Q#F#H#G#L#D#R#D#Q# +RQJ 0 + +LJK TXDOLW\
VSHFWURVFRS\ ZLWK \$X QDQRSDUWLF#O#H V#R#E#R#U#S#U#R#H#H#D#E#L#L#F#D#E#H#G#X#E#D#O E#H#D#P ODVHU
XVLQJ IHPWRVHFRQG SXOVH>-@ 1DQR#W#H#F#K#Q#R#O#L#W#H#G DEODWLRQ>-@ 2SW ([SUHV#V
> @DKPDQ 7 8 5HKPDQ = 8 8OODK 6 HW DO
> @/RQJ - < &DR = /LQ & + HW DO)RUP#D#W#L#S#O#D#P#H#D#D#L#W#P#R#G DEODWLRQ /,3\$\$ RI JO
KL#H#U#D#U#F#K#L#F#D#O 0#L#F#U#R DQG QDQRVWUXFWX#U#H#D#W#I#R#Q F#O#S#H#J#F#H#Q#K#F#H#G#E#D#V#P#D SDUDPHWH
ORZ FRVW QDQRVHFRQG ODVHU#V>-@ \$SSO#R#U#S#K#R#E#U#E#D#S#K#L#O#L#F#P#L#F#U#R#S#R#X#V#S
í > @DUDHYD , 1 .XGU#D#V#K#R#Y 6 , /HGQHY 9 1 HW
> @+DULODO 6 6 %LQGKX & 9 7LOODFN 0 6 H#V#D#D#L#V#K#R#U#D#D#P#R#W#H#F#O#G#L#D#V#H#U DEODWLRQ
DQG H[SDQVLQJ G\QDPLFV RI ODVHU DE#D#L#W#L#B#Q#G#S#O#K#P#H#G#L#Q#W#R#U#R#Q#P#H#Q#V#V 3OXPH G
DPELHQW JDVHV>-@ - \$SSO 3K\V P#R#G#L#I#F#D#W#L#R#Q>-@ \$SSO 6XUI 6FL
> @&DL 0 < 3DQ 5 /LX : - HW DO /DVHU#D#V#V#E#D#D#G#D#R#S#(Q#I#L#D#O#G# - - - 9DODGDQ 0 HW D
DUFKLWHFWXUH HQLQHHULQJ RI)H 2 QD#R#S#D#W#L#F#O#H#X#O#R#U#D#K#L#V#W#O#D#V#H#U VXUIDFH WH
HQKDQFHG R[)JHQ HYROXWLRQ UHDFWLRQ#H#S#H#W#L#F#R#X#U#D#W#H#P LQ DLU>-@ \$SSO 6XUI 6FL
í > @HQJ & < 7LQJ & 6 /HH 7 . 0RELOH VSLQ E
> @'LOHHS 0 0DMXPGDU - ' 6KRUW DQG XOW#U#D#M#R#U#D#F#O#D#R#E#U#L#Q#X#W#K#D#F#V#L#Q GHQVLW\ ZDYH E
SURFHVV#L#Q#J RI \$OSKD %HWD WLWDQLXP D#O#R# 7L \$O 9 í 3UH#V#H#Q#W
V#D#W#X#V>-@ 7UDQV ,QGLDQ 1DWO \$FDG (Q#K#L)K#F#K#H#Q#N#R#i\$.X#F#K#P#L#K#D#N \$ 9LW#L#N 2 HW
> @\$JDUZDO 5 /)DUUDU / : 'LHEROG (' HW D#R#Q#R#H#O#W#D#W#R#R#Q#W RI DQ DQDO\#W#H RQ
RI WKH DEVROXWH 5DPDQ VFDWWHULQJ FUR#S#O#V#H#F#W#L#B#D#I#E#K#M#K#R#H#W#K#I#H#Q#H>-@ 1DQR#V#F#D#O
EDQG RI EHQ]H#Q#H#W#K#L#R#O DQG WKH VXUIDFH HQKDQFHG 5DPDQ
VFDWWHULQJ FURVV VHF#W#L#R#Q HQKDQFH#P#H#O#D#D#Q#D#E#W#;#R#U#=#K#P#D#J#H#P#R#V#H#F#R#Q#G HW DO 6XSHU

‡•-‘•‡...‘•† Žf•‡” † ‹” ‡...- TM” ‹- ‹•%00 ’
 •—„•-” f-‡• f•† f’’ Ž ‹... f- ‹‘•
 ‹• Š ‹†‘•%00^sá ‹ f ‹† ‹•%00^tá — ‹ œŠ—^sá f‘ Šf‘š ‹•^s

)RXU PHWKRGV RI IHPWRVHFRQG ODVHU SUHSDUDWLRQ 6(56 VXEVWUD

2YHUYLHZ 4VSGBDF &OIBODFE 3BNBO TQFDUSPTDPQZ 4&34 JT B IJ
 SFDPHOJUJPO UFDIOJRVF XJUI JNQPSUBOU BQQMJDBUJPO JT NBOZ GJ
 GMFYJCMJUZ NJDSP OBOP QSPDFTTJOH NFUIPE GFNUPTFDPOE MBTF
 QSFQBSJOH 4&34 TVCTUSBUFT \$PNQBSFE XJUI USBEJUJPOBM QSPDFTT
 MBTF EJSFJU XSJUJJOH QSPDFTTJOH IBT DFSUBJO BEWBOUBHFT JO U
 NBUFSJBM SBOHF QSPDFTTJOH BDDVSBZ BOE PUIFS BTQFDUT *O
 GFNUPTFDPOE MBTF QSFQBSBUJPO PG 4&34 TVCTUSBUFT JOUP GPVS
 SFEVDUJPO GFNUPTFDPOE MBTF DVUUJJOH NFUBM GFNUPTFDPOE MBT
 'FNUPTFDPOE MBTF UXP QIPUPO NFUBM SFEVDUJPO VTFT UIF UXP QIP
 TPMVUJPO UP NFUBM TVDI BT TJMWFS JPOT JO TJMWFS OJUSBUFT TP
 POF TUFQ QSFQBSBUJPO PG 4&34 TVCTUSBUFT JO DMPTFE NJDSPDIBOO
 4&34 TVCTUSBUFT TUSVDUVSF PO B NFUBM TVCTUSBUFT 5IJT NFUIPE UBL
 MBTF UP BCMBUF UIF TVSGBDF PG UIF NFUBM TBNQMF UP PCUBJO B C
 MBTF BCMBUJPO QSPEVDFT QBSUJDMF GSBHNFOUT XIJDI BSF VTBMM
 TQPUT 'FNUPTFDPOE MBTF EJSFJU DVUUJJOH PG NFUBM DBO QSFQBS
 IJHI QSPDFTTJOH FGGJDFODZ BOE TJNQMF QSPDFTTJOH BOE JT NPSF
 QSDUJDBM 4&34 EFUFDUJPO 'FNUPTFDPOE MBTF DVUUJJOH TQVUUF
 TVDI BT QPMZNFST BOE UIF TQVUUFJSJOH FWBQPSBUJJOH NFUBM OBOP
 QSFQBSF USBOTQBSFOU BOE GMFYJCMF 4&34 TVCTUSBUFT XIJDI BSF S
 JT UP VTF UIF UISFF EJNFOTJPOBM QSPDFTTJOH BCJMJUJ PG GFNUPT
 TUSVDUVSF PG 4&34 TVCTUSBUFT BOE UIF VTJOH UFNQMBUF HVJEFE
 EFQPTJU FWBQPSBUF NFUBM OBOPQBSUJDMFT BU EFTJHOBUE MPDBUJ
 QSFQBSJOH 4&34 BOE UIF DPOEVDU B DPNQSFIFOTJWF SFWJFX PG UI
 QSFQBSF 4&34 TVCTUSBUFT 'JOBMMZ UIF BEWBOUBHFT BOE EJTBEWBO
 GPS 4&34 TVCTUSBUFT BSF CSJFGMZ TVNNBSJ[FE BOE UIF EFWFMPQNFO
 QSPWJEF JU GPS GVUVSF SFMBUFE SFTFBSDI

<LQ = ' 1L & ' :X 6 = HW DO)HPWRVHFRQG ODVHU GLUHFV ZULWLQJ SURFHVV
 (OHFWURQ (QJ '2, RHH

)RXQGDWLRQ LWHP 1DWLRQDO 1DWXUDO 6FLHQFH)RXQGDWLRQ RI &KLQD DQG WK
 -= +*3\$
 +HIHL 8QLYHUVLW\ RI 7HFKQRORJ\ 6FKRRO RI ,QVWUXPHQW 6FLHQFH DQG 2SWRHOHFWRUQL
 6FLHQFH DQG 7HFKQRORJ\ RI &KLQD 6FKRRO RI (QJLQHULQJ 6FLHQFHV +HIHL \$QKXL &
 (PDLO ODR][#KIXW HGX FQ